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Agency

Demonstration of Biodegradation of DNAPL through Biostimulation and Bioaugmentation at Launch Complex 34 in Cape Canaveral Air Force Station, Florida

Innovative Technology Evaluation Report

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

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Demonstration of Biodegradation of Dense, Nonaqueous-Phase Liquids (DNAPL) through Biostimulation and Bioaugmentation at Launch Complex 34 in Cape Canaveral Air Force Station, Florida

Final Innovative Technology Evaluation Report

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Appendix A

Performance Assessment Methods

Appendix A.1 Summary of Statistics in Biostimulation and Bioaugmentation Plot

This document summarizes the results of the statistical analyses of TCE data in soil samples from the biostimulation and bioaugmentation treatment plot. In this case, two different analyses were performed: one used the summary statistics of the data without considering the spatial information, the other used kriging to account for the spatial correlation of the data.

Soil Monitoring Data

Soil coring data were collected from three stratigraphic layers: Lower Sand Unit, Middle Fine-Grained Unit, and Upper Sand Unit, before and after the bioaugmentation treatment (pre-demonstration and post-demonstration data). The technology demonstration was performed only in the Upper Sand Unit, but statistical analysis was performed in all the three units. The Middle Fine-Grained Unit and the Lower Sand Unit were considered as control groups to assess the results obtained from the Upper Sand Unit. If a drastic reduction of the TCE concentration was observed in the Upper Sand Unit, while a significant increase in the Middle Fine-Grained Unit was observed, it could be considered that the TCE simply migrated from one unit to the other. On the other hand, if a drastic reduction in TCE concentration was observed in both the Upper Sand Unit and Middle Fine-Grained Unit, and knowing that the Middle Fine-Grained Unit had not been treated directly, the reduction in TCE concentration may have been due to natural attenuation rather than to the treatment process.

Originally, the biostimulation and bioaugmentation plot was defined on a "nearly-rectangular" quadrilateral having a surface of about 430 ft^2. To simplify the statistical analysis, a slightly different rectangular surface of 400 ft^2 was used in the calculations. This affected the calculations of the total masses of TCE by a few percent, which is abundantly within the confidence limits of the results. All stratigraphic units in the Upper Sand Unit, Middle Fine-Grained Unit and Lower Sand Unit were assumed to be horizontal with a constant thickness of 18, 10, and 10 feet, respectively.

Summary Statistics Analysis

The simple average and the simple variance of the pre-demonstration and the post-demonstration data for the three units were calculated as shown in Table A.1-1. The data were not weighted to account for possible spatial correlations. The values obtained for the pre- and post-demonstration data were compared, unit by unit, to assess the mean change in the TCE concentration and its confidence limits. The change was expressed both as a difference and as a percentage reduction in Table A.1-2.

Table A.1-1. Summary Statistics of TCE Concentration Resulting from Pre- and Post-Demonstration Monitoring

Statigraphic Unit	Mean (mg/kg)	Variance	Lower Bound (mg/kg)	Upper Bound (mg/kg)
Pre-Demonstration				
Upper Sand Unit	81.58	776.66	45.85	117.30
Middle Fine-Grained Unit	995.14	155,006.20	490.40	1,499.87
Lower Sand Unit	762.75	80,355.42	399.34	1,126.16
Post-Demonstration				
Upper Sand Unit	0.62	0.04	0.36	0.87
Middle Fine-Grained Unit	967.74	279,611.75	289.84	1,645.64
Lower Sand Unit	1,367.27	280,689.95	688.07	2,046.48

Table A.1-2. Mean Changes inTCE Concentrations after the Biostimulation and Bioaugmentation Treatment

Statigraphic Unit	Mean (mg/kg)	Variance	Lower Bound (mg/kg)	Upper Bound (mg/kg)	80% Lower Bound (mg/kg)
Differences in TCE Concentrations (pre- post)					
Upper Sand Unit	80.96	776.70	45.23	116.69	57.55
Middle Fine-Grained Unit	27.40	434,617.95	-817.77	872.56	-526.38
Lower Sand Unit	-604.52	361,045.37	-1,374.84	165.79	-1,109.25
% Reduction = (1 - Post / Pre) * 100					
	Mean (mg/kg)	**Median (mg/kg)**	**10%**	**90%**	
Upper Sand Unit	99.08	99.25	98.53	99.61	98.86
Middle Fine-Grained Unit	-60.52	3.61	-127.83	73.77	-67.33
Lower Sand Unit	-94.55	-77.93	-274.59	19.09	-183.91

Kriging Analysis

A weighted average and a weighted variance of TCE concentrations in the soil of the target treatment zone (i.e., Upper Sand Unit) were calculated before and after the treatment. The weights, accounting for the spatial correlation in the data, were evaluated through the variogram model. Nearly continuous TCE data were available from four soil cores in the entire surficial aquifer (i.e., all three stratigraphic units), and continuous soil core data in the saturated zone of the Upper Sand Unit. Less continuous TCE concentration data was available for the horizontal plane. It was assumed that the covariance among a pair of data depends on their relative distance but not on the direction. As a result, an isotropic variogram was calculated.

Results

Both the summary statistical analysis and the kriging analysis showed a drastic reduction in TCE concentrations in the Upper Sand Unit. Confidence limits for the mean were considered to be a two-sided, 80% limit. To evaluate the confidence limits, a normal distribution assumption was assumed for the mean. Within those limits, the summary statistics analysis of the Middle Fine-Grained Unit and Lower Sand Unit layers did not show a statistically significant change in their concentrations, which indicates that the reduction in TCE concentrations in the Upper Sand Unit was mainly due to the biostimulation and bioaugmentation technology.

The percentage reduction in TCE concentrations in the Upper Sand Unit as predicted by the summary statistic has a two sided, 80% confidence interval of between 98.53 and 99.61, which indicates that almost all the TCE is no longer present. The pre and post-demonstration two-sided 80% confidence intervals are [14.86, 38.03] and [0.12, 0.28], respectively, with a confidence limit of [14.66, 37.83] for the difference between pre- and post-demonstration. (Note that the confidence limits of a difference are not equal to the difference of the confidence limits. However, the center of the confidence interval of a difference, is equal to the difference of the centers of the confidence intervals.)

The percentage reduction in the Upper Sand Unit as predicted by the kriging analysis has a two sided 80% confidence interval of [98.55, 99.66], which is consistent with that obtained by the simple summary analysis. The pre- and post-demonstration two-sided 80% confidence intervals are [18.92, 50.14] and [0.12, 0.34], respectively, with a confidence limit for the difference between pre- and post-demonstration of [17.37, 46.41]. Those intervals are also consistent (that is, overlapping), with the ones obtained in the summary analysis.

The consistency between the summary and kriging results indicated that the samples were spatially well distributed. It reflects the absence of clusters of data that, in the simple average, would over-weight a certain region of space respect to the others.

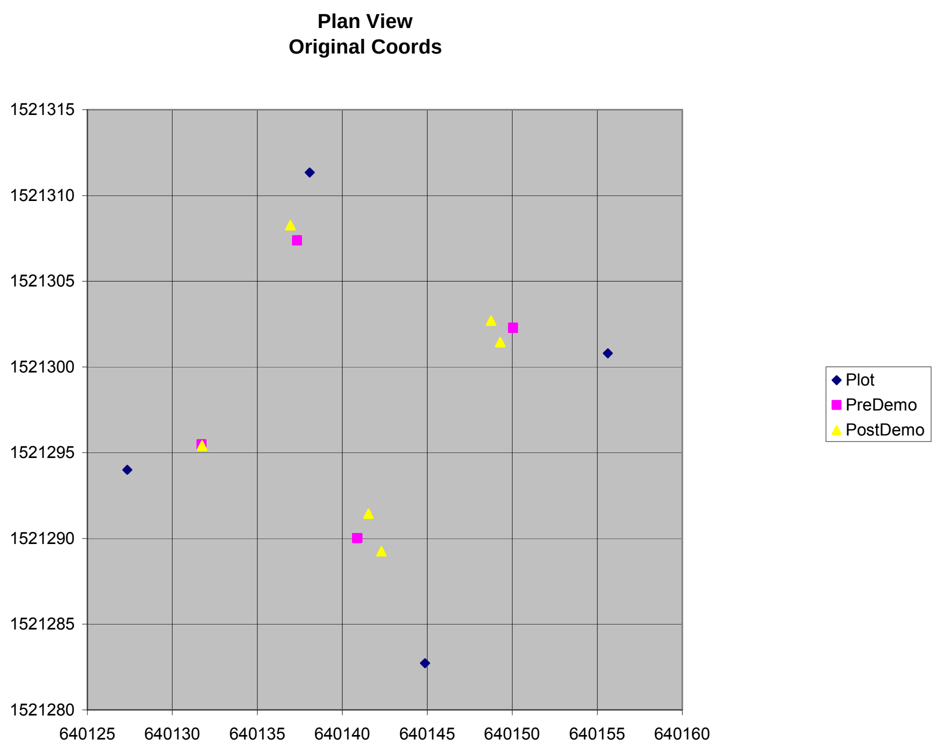


Figure A.1-1. Locations of Soil Coring Locations and Plot Boundary

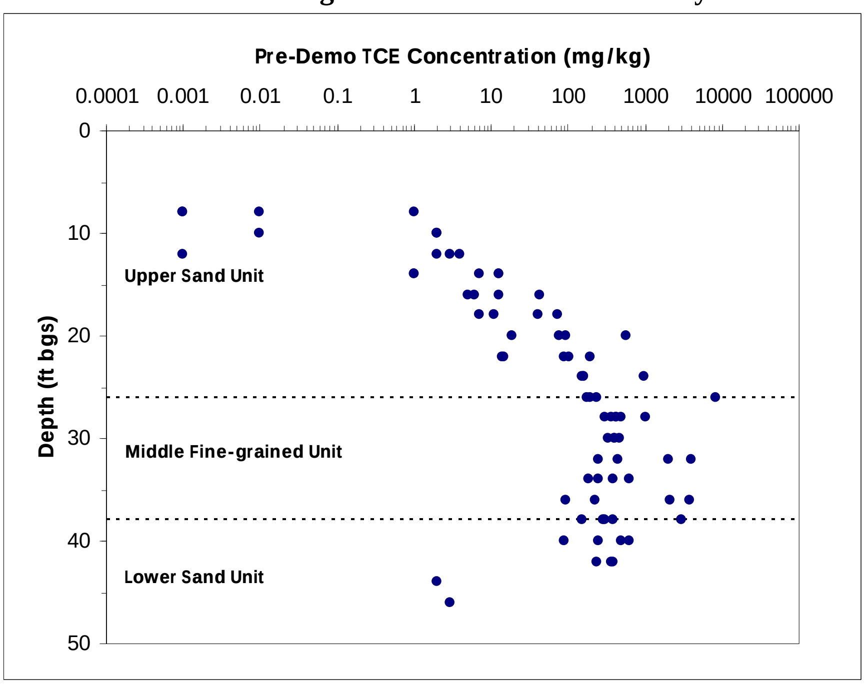


Figure A.1-2. TCE Concentration Distribution of Pre-demonstration Soil Samples Before the Biostimulation and Bioaugmentation Treatment

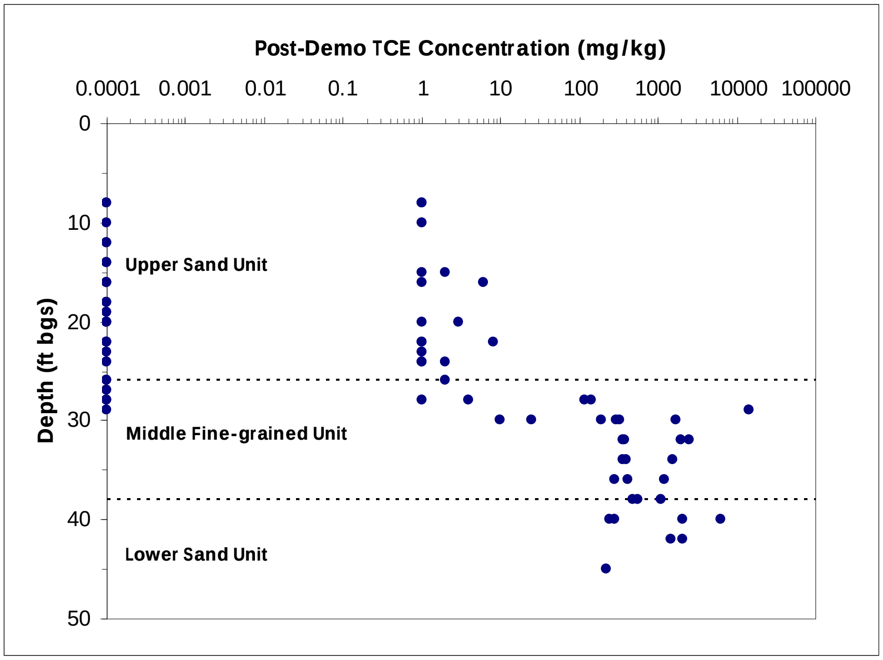


Figure A.1-3. TCE Concentration Distribution of Post-demonstration Soil Samples After the Biostimulation and Bioaugmentation Treatment

A.2 Sample Collection and Extraction Methods

This section describes the modification made to the EPA standard methods to address the lithologic heterogeneities and extreme variability of the contaminant distribution expected in the DNAPL source region at Launch Complex 34. Horizontal variability was addressed by collecting a statistically determined number of soil cores in the bioaugmentation plot. The vertical variability at each soil coring location was addressed with this modified sampling and extraction procedure, which involved extraction of much larger quantities of soil in each extracted sample, as well as allowed collection and extraction of samples in the field per event. This extraction allowed the extraction and analysis of the entire vertical column of soil at a given coring location.

A.2.1 Soil Sample Collection (Modified ASTM D4547-91) (1997b)

The soil samples collected before and after the demonstration were sampled using a stainless steel sleeve driven into the subsurface by a Vibra-push LD-2 rig. After the sleeve had been driven the required distance, it was brought to the surface and the soil sample was examined and characterized for lithology. One quarter of the sample was sliced from the core and placed into a pre-weighed 500-mL polyethylene container containing methanol. At locations where a field duplicate sample was collected, a second one-quarter sample was split from the core and placed into another pre-weighed 500-mL polyethylene container containing methanol. The remaining portion of the core was placed into a 55-gallon drum and disposed of as waste. The samples were labeled with the date, time, and sample identification code, and stored on ice at 4°C until they were brought inside to the on-site laboratory for the extraction procedure.

After receiving the samples from the drilling activities, personnel staffing the field laboratory performed the methanol extraction procedure as outlined in Section A.2.2 of this appendix. The amount of methanol used to perform the extraction technique was 250 mL. The extraction procedure was performed on all of the primary samples collected during drilling activities and on 5% of the field duplicate samples collected for quality assurance. Samples were stored at 4°C until extraction procedures were performed. After the extraction procedure was finished, the soil samples were dried in an oven at 105°C and the dry weight of each sample was determined. The samples were then disposed of as waste. The remaining three-quarter section of each core previously stored in a separate 500-mL polyethylene bottle were archived until the off-site laboratory had completed the analysis of the methanol extract. The samples were then disposed of in an appropriate manner.

A.2.2 Soil Extraction Procedure (Modified EPA SW846-Method 5035)

After the soil samples were collected from the drilling operations, samples were placed in pre-labeled and pre-weighed 500-mL polyethylene containers with methanol and then stored in a refrigerator at 4°C until the extraction procedure was performed. Extraction procedures were performed on all of the “A” samples from the outdoor and indoor soil sampling. Extraction procedures also were performed on 5% of the duplicate (or “B”) samples to provide adequate quality assurance/quality control (QA/QC) on the extraction technique.

Extreme care was taken to minimize the disturbance of the soil sample so that loss of volatile components was minimal. Nitrile gloves were worn by field personnel whenever handling sample cores or pre-weighed sample containers. A modification of EPA SW846-Method 5035 was used to procure the cored samples in the field. Method 5035 lists different procedures for processing samples that are expected to contain low concentrations (0.5 to 200 μg/kg) or high concentrations

(>200 μg/kg) of volatile organic compounds (VOCs). Procedures for high levels of VOCs were used in the field because those procedures facilitated the processing of large-volume sample cores collected during soil sampling activities.

Two sample collection options and corresponding sample purging procedures are described in Method 5035; however, the procedure chosen for this study was based on collecting approximately 150 to 200 g of wet soil sample in a pre-weighed bottle that contains 250 mL of methanol. A modification of this method was used in the study, as described by the following procedure:

- The 150 to 200 g wet soil sample was collected and placed in a pre-weighed 500 mL polypropylene bottle filled with 250 mL of methanol. After capping, the bottle was reweighed to determine the total weight of the soil and the bottle with methanol. The bottle was marked with the location and the depth at which the sample was collected.

- After the containers were filled with methanol and the soil sample they were placed on an orbital shaker table and agitated for approximately 30 min.

- Containers were removed from the shaker table and reweighed to ensure that no methanol was lost during the agitation period. The containers were then placed upright and suspended soil matter was allowed to settle for approximately 15 min.

- The 500 mL containers were then placed in a floor-mounted centrifuge. The centrifuge speed was set at 3,000 rpm and the samples were centrifuged for 10 min.

- Methanol extract was then decanted into disposable 20-mL glass volatile organic analysis (VOA) vials using 10-mL disposable pipettes. The 20-mL glass VOA vials containing the extract then were capped, labeled, and stored in a refrigerator at 4°C until they were shipped on ice to the analytical laboratory.

- Methanol samples in VOA vials were placed in ice chests and maintained at approximately 4°C with ice. Samples were then shipped with properly completed chain-of-custody forms and custody seals to the subcontracted off-site laboratory.

- The dry weight of each of the soil samples was determined gravimetrically after decanting the remaining solvent and drying the soil in an oven at 105°C. Final concentrations of VOCs were calculated per the dry weight of soil.

Three potential concerns existed with the modified solvent extraction method. The first concern was that the United States Environmental Protection Agency (U.S. EPA) had not formally evaluated the use of methanol as a preservative for VOCs. However, methanol extraction often is used in site characterization studies including three technology demonstrations at Launch Complex 34 under U.S. EPA Superfund Innovative Technology Evaluation (SITE) program, so the uncertainty in using this approach was reasonable. The second concern was that the extraction procedure itself would introduce a significant dilution factor that could raise the method quantitation limit beyond that of a direct purge-and-trap procedure. The third concern was that excess methanol used in the extractions would likely fail the ignitability characteristic, thereby making the unused sample volume a hazardous waste. During characterization activities, the used methanol extract was disposed of as hazardous waste into a 55-gallon drum. This methanol extraction method was tested during preliminary site characterization activities at this site (see Appendix G, Table G-1) and, after a few refinements, was found to perform acceptably in terms of matrix spike recoveries. Spiked TCE recoveries in replicate samples ranged from 72 to 86%.

The analytical portion of Method 5035 describes a closed-system purge-and-trap process for use on solid media such as soils, sediments, and solid waste. The purge-and-trap system consists of a unit that automatically adds water, surrogates, and internals standards to a vial containing the sample. DHL Analytical performed the analysis of the solvent extraction samples by Gas chromatogram/mass spectrum (GC/MS). Soil samples were analyzed for organic constituents according to the parameters summarized in Table A.2-1. Laboratory instruments were calibrated for VOCs listed under U.S. EPA Method 601 and 602. Samples were analyzed as soon as was practical and within the designated holding time from collection (14 days). No samples were analyzed outside of the designated 14-day holding time.

Table A.2-1. Soil Sampling and Analytical Parameters

Analytes	Extraction Method	Analytical Method	Sample Holding Time	Matrix
VOCs[a]	SW846-5035	SW846-8260	14 days	Methanol

(a) EPA 601/602 list.

A.3 List of Standard Sample Collection and Analytical Methods

Table A.3-1. Sample Collection Procedures

Measurements	Task/Sample Collection Method	Equipment Used
Primary Objectives		
CVOCs	Soil sampling/ Mod.[a] ASTM D4547-98 (1997c)	Butyrate or acetate sleeves 500-mL plastic bottle
CVOCs	Groundwater sampling/ Mod.[a] ASTM D4448-01 (1997a)	Peristaltic pump Teflon™ tubing
DHG[b]	Groundwater sampling/ Mod.[a] ASTM D4448-01 (1997a)	Peristaltic pump Teflon™ tubing
PCR[c]	Groundwater sampling/ Mod.[a] ASTM D4448-01 (1997a)	Peristaltic pump Teflon™ tubing
Secondary Objectives		
Field parameters[d] Inorganics–cations Inorganics–anions TOC, BOD, TDS, dissolved silica Alkalinity	Groundwater sampling/ Mod.[a] ASTM D4448-01 (1997a)	Peristaltic pump Teflon™ tubing
Hydraulic conductivity	Hydraulic conductivity/ ASTM D4044-96 (1997d)	Winsitu® data logger Laptop computer
Groundwater level	Water levels	Water level indicator

(a) Modifications to ASTM are detailed in Appendix B.
(b) DHG: methane, ethene, and ethane (see Appendix D).
(c) PCR: Polymerase chain reaction (see Appendix C).
(d) Field parameters include pH, ORP, temperature, DO, and conductivity. A flow-through cell will be attached to the peristaltic pump when measuring field parameters.
ASTM = American Society for Testing and Materials.

Table A.3-2. Sample Handling and Analytical Procedures

Measurements	Matrix	Amount Collected	Analytical Method	Maximum Holding Time[a]	Sample Preservation[b]	Sample Container	Sample Type
Primary Objectives							
CVOCs	Soil	250 g	Mod. EPA 8260[c]	14 days	4°C	Plastic	Grab
CVOCs	Groundwater	40-mL × 3	EPA 8260	14 days	4°C, pH < 2 HCl	Glass	Grab
DHG[d]	Groundwater	40 mL x 3	RS Kerr Method	7 days	4°C	Glass	Grab
Dehalococcoidis Ethenogenes[e]	Groundwater	2 x 1L	GeneTrac™ [e]	30 days	4°C	Plastic	Grab
Secondary Objectives							
Hydraulic conductivity	Aquifer	NA	ASTM D4044-96 (1997d)	NA	NA	NA	NA
Inorganics–cations[f]	Groundwater	100 mL	EPA 200.8	28 days	4°C	Plastic	Grab
Inorganics–anions[f]	Groundwater	50 mL	EPA 300.0	28 days	4°C	Plastic	Grab
Dissolved silica	Groundwater	250 mL	SW6010	28 days	None	Plastic	Grab
TOC	Soil	20 g	Based on SW9060	28 days	None	Plastic	Grab
TOC	Groundwater	500 mL	EPA 415.1	7 days	4°C, pH < 2 H_2SO_4	Plastic	Grab
TDS	Groundwater	500 mL	EPA 160.1	7 days	4°C	Plastic	Grab
BOD	Groundwater	1,000 mL	EPA 405.1	48 hours	4°C	Plastic	Grab
DHG[d]	Groundwater	40 mL x 3	RS Kerr Method	7 days	4°C	Glass	Grab
Alkalinity	Groundwater	200 mL	EPA 310.1	14 days	4°C	Plastic	Grab
Water levels	Aquifer	NA	Water level from the top of well casing	NA	NA	NA	NA

(a) Samples will be analyzed as soon as possible after the samples arrive in an off-site laboratory. The times listed are the maximum holding times that samples will be held before analysis and still be considered valid. All data obtained beyond the maximum holding times will be flagged.
(b) Samples will be preserved immediately upon sample collection, if required.
(c) Samples will be extracted using methanol on site. For the detailed extraction procedure see Appendix B.
(d) Dissolved hydrocarbon gases are analyzed by R.S. Kerr Method (see Appendix D).
(e) GeneTrac™ is a proprietary method (see Appendix C).
(f) Cations include Ca, Mg, total and dissolved Fe, Mn, K, and Na. Anions include Br, Cl, SO_4, PO_4, NO_3/NO_2 and Alkalinity.
HCl = Hydrochloric acid, H_2SO_4 = Sulfuric acid.
NA = Not applicable.

Appendix B

Hydrogeologic Measurements

B.1 Slug Tests
B.2 Well Completion Diagrams
B.3 Soil Coring Logsheets

Appendix B. Slug Tests

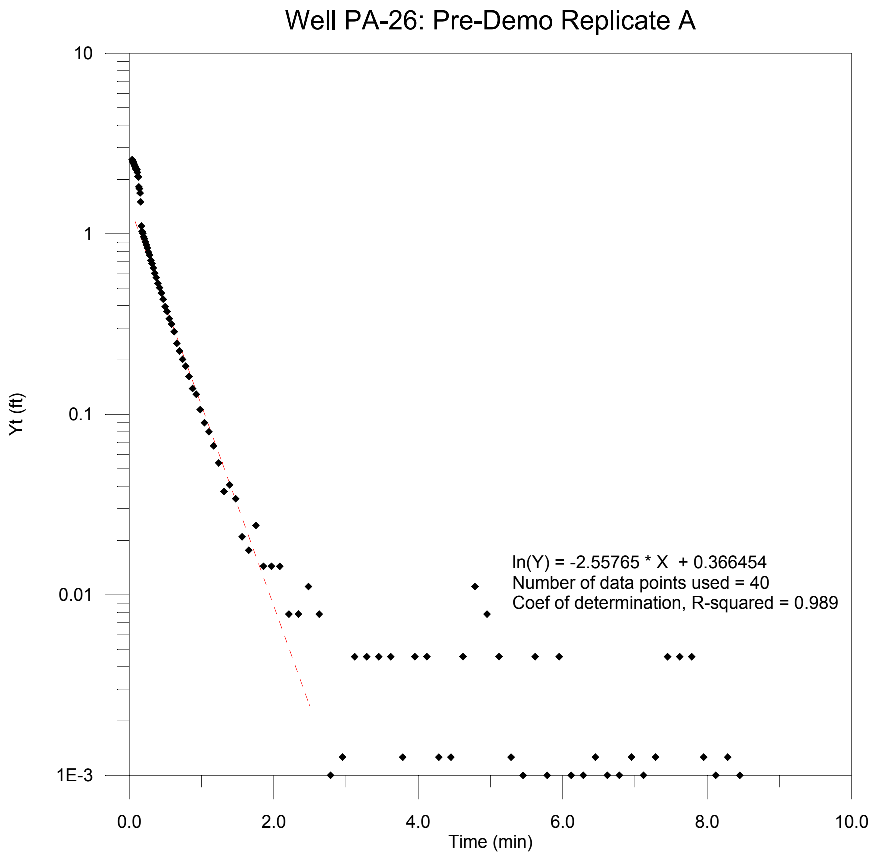
Slug tests were performed on well PA-26 in the biostimulation and bioaugmentation plot before and after the demonstrations to assess any effects on aquifer quality caused by the remediation technologies. Pre-demonstration tests were conducted in the well in March 2002. Post-demonstration tests were completed in well PA-26 in June 2003. As the remediation treatment was applied to just the Upper Sand Unit, slug tests were only performed in the shallow performance monitoring well in the center of the plot. PA-26 is 24 ft deep with a 5-ft long screen. The tests consisted of placing a pressure transducer (Mini Troll™) and 1.5-inch-diameter by 5-ft-long solid PVC slug within the well. After the water level reached equilibrium, the slug was quickly removed. Removal of the slug created approximately 1.0 ft of change in water level within the well. Water level recovery was then monitored for at least 5 minutes using a Mini TROLL® pressure transducer/data logger. The data was then downloaded to a notebook computer. Three replicate tests were conducted in each well to ensure repeatable results.

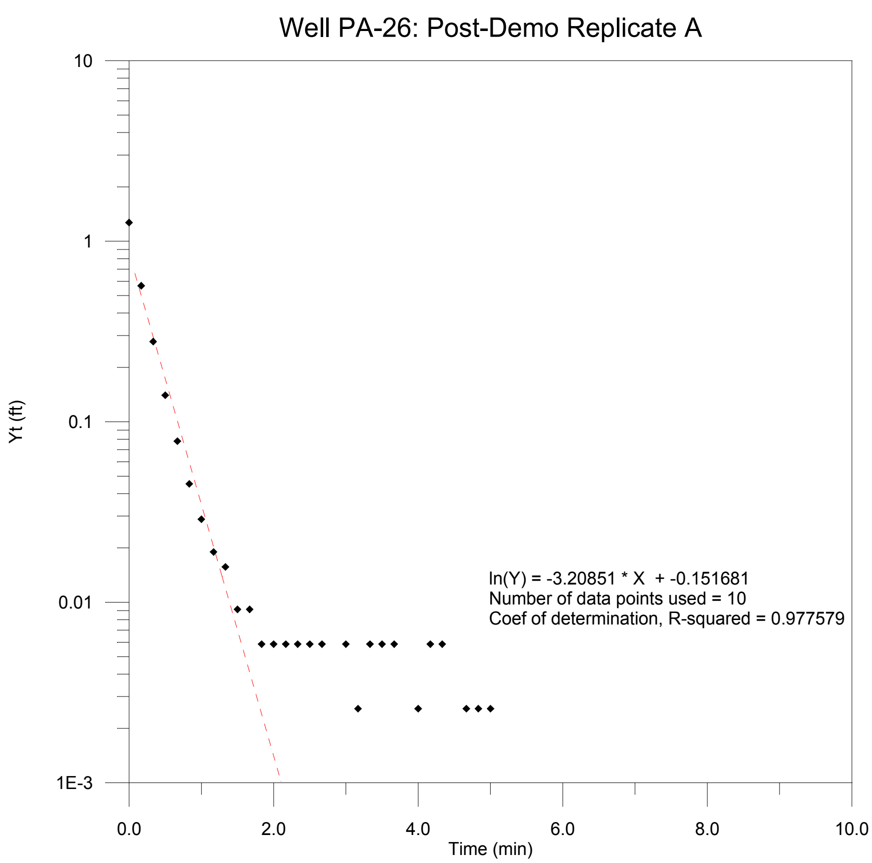
The recovery rates of the water levels were analyzed with the Bouwer (1989) and Bouwer and Rice (1976) methods for slug tests in unconfined aquifers with partially penetrating wells. Graphs were made showing the changes in water level versus time and curve fitted on a semi-logarithmic graph. The slope of the fitted line then was used in conjunction with the well parameters to provide a value of the hydraulic conductivity of the aquifer materials surrounding the well.

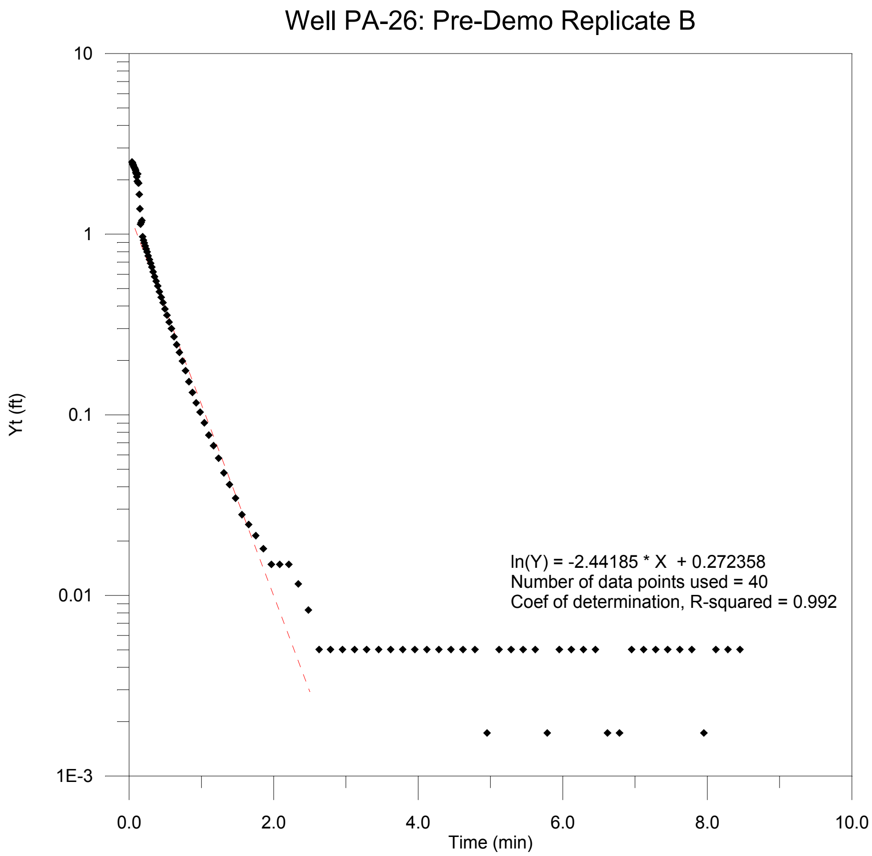
Slug test response curves are presented in this Appendix B. Water levels returned to equilibrium within 5 minutes for all the tests. Response curves were excellent with coefficients of determination of 0.95 or greater. Table 1 summarizes the results of the slug tests. The results show a very good agreement between the replicate tests. Comparison of the pre-demonstration and post-demonstration slug test results shows mostly negligible changes due to inherent variations in the testing methods. A change of 10 times or greater would indicate a substantial change in permeability at the site. Pre-demonstration hydraulic conductivity averaged 22 ft/day (0.0079 cm/sec) in well PA-26. These values are comparable to the typical hydraulic conductivity range in the Upper Sand Unit at LC34, which is usually higher than in the underlying hydrostratigraphic units. Post-demonstration hydraulic conductivity averaged at 32.3 ft/day (0.011 cm/sec) in PA-26. These data indicate that the biostimulation and bioaugmentation technology did not affect the hydraulic conductivity of the Upper Sand Unit.

Table 1. Slug Test Results in Biostimulation and Bioaugmentation Plot

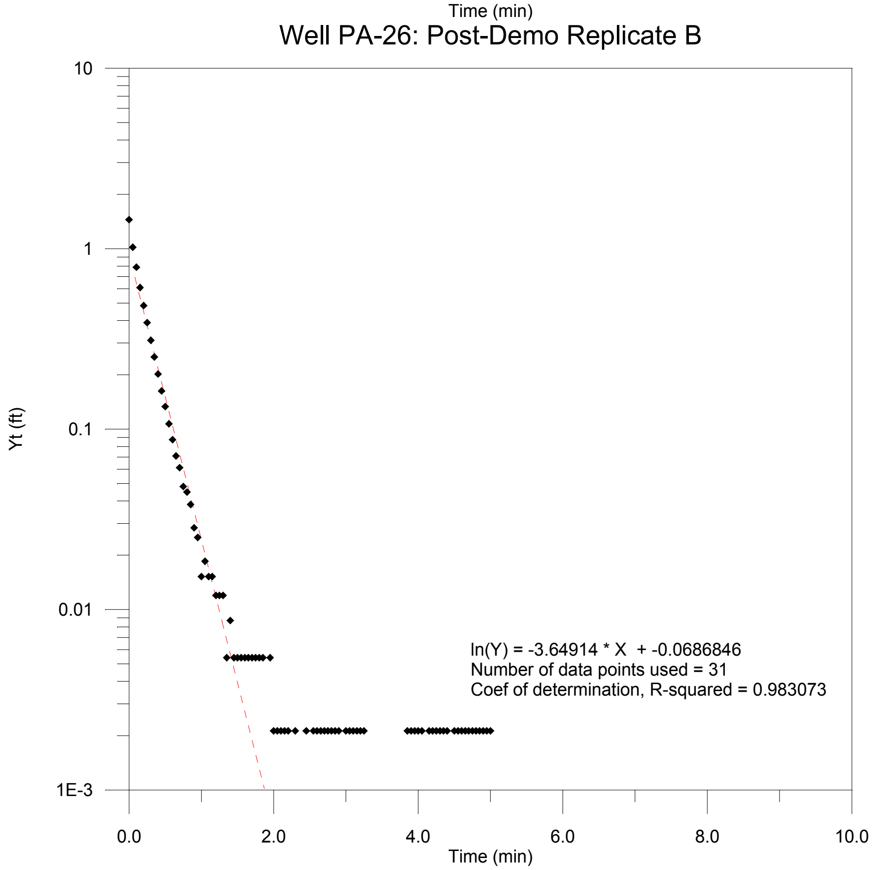
<table>
<tr><th>Well</th><th>Test</th><th>Hydraulic Conductivity (ft/day)</th><th>Hydraulic Conductivity (cm/s)</th><th>Response (r^2)</th></tr>
<tr><td rowspan="9">PA-26</td><td colspan="4">Pre-Demonstration</td></tr>
<tr><td></td><td>22.5</td><td>0.0079</td><td>Excellent (0.989)</td></tr>
<tr><td></td><td>21.5</td><td>0.0076</td><td>Excellent (0.992)</td></tr>
<tr><td></td><td>23.0</td><td>0.0081</td><td>Excellent (0.997)</td></tr>
<tr><td colspan="4">Post-Demonstration</td></tr>
<tr><td>A</td><td>29.3</td><td>0.0100</td><td>Excellent (0.977)</td></tr>
<tr><td>B</td><td>33.5</td><td>0.0118</td><td>Excellent (0.997)</td></tr>
<tr><td>C</td><td>34.1</td><td>0.0120</td><td>Excellent (0.983)</td></tr>
</table>


Well PA-26: Pre-Demo Replicate A
10
1
0.1
0.01
1E-3
Yt (ft)
0.0
2.0
4.0
6.0
8.0
10.0
Time (min)
ln(Y) = -2.55765 * X + 0.366454
Number of data points used = 40
Coef of determination, R-squared = 0.989

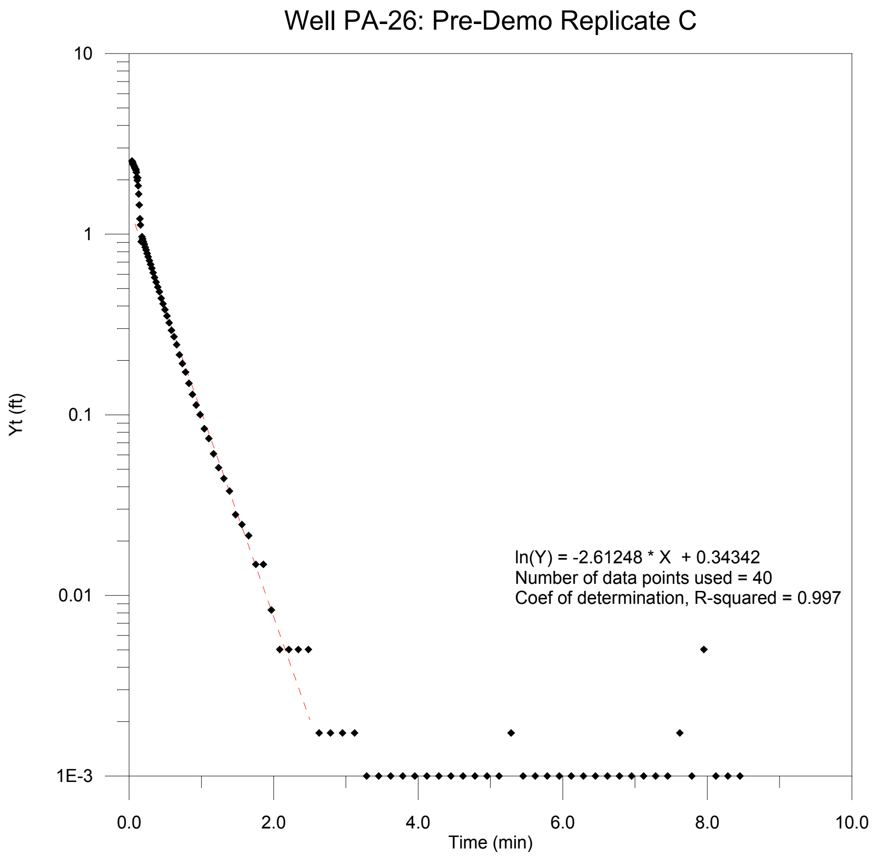

Well PA-26: Post-Demo Replicate A
10
1
0.1
0.01
1E-3
Yt (ft)
0.0
2.0
4.0
6.0
8.0
10.0
Time (min)
ln(Y) = -3.20851 * X + -0.151681
Number of data points used = 10
Coef of determination, R-squared = 0.977579

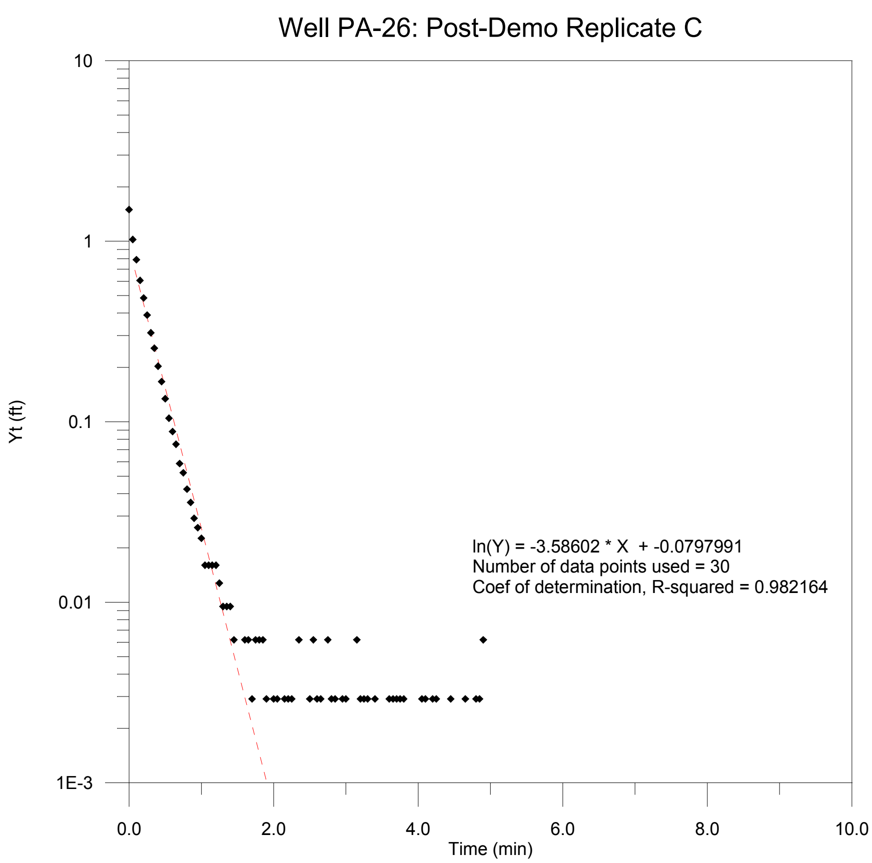


Well PA-26: Pre-Demo Replicate B
10
1
0.1
0.01
1E-3
Yt (ft)
0.0
2.0
4.0
6.0
8.0
10.0
Time (min)
ln(Y) = -2.44185 * X + 0.272358
Number of data points used = 40
Coef of determination, R-squared = 0.992



Well PA-26: Post-Demo Replicate B
10
1
0.1
0.01
1E-3
Yt (ft)
0.0
2.0
4.0
6.0
8.0
10.0
Time (min)
ln(Y) = -3.64914 * X + -0.0686846
Number of data points used = 31
Coef of determination, R-squared = 0.983073

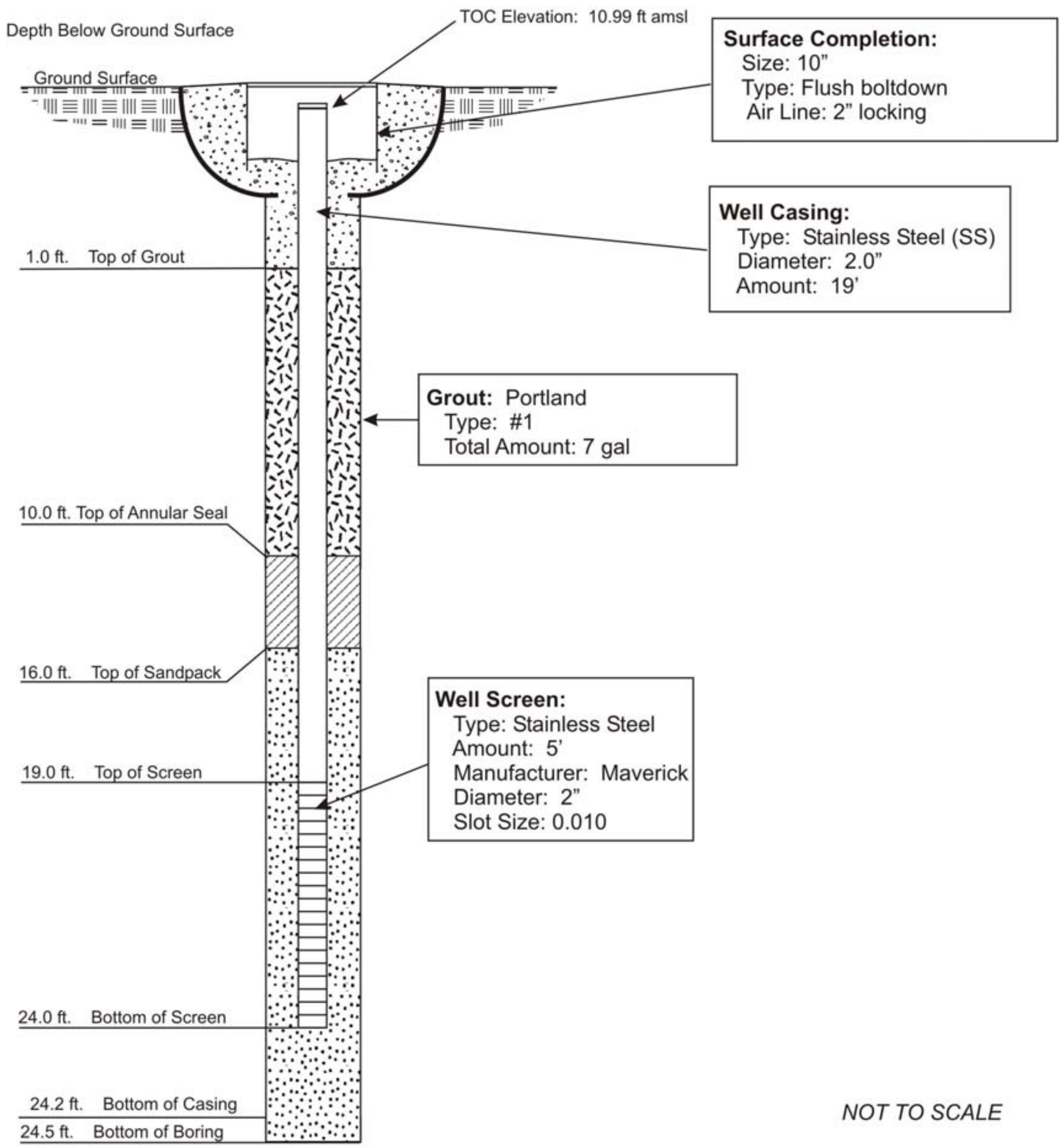

Well PA-26: Pre-Demo Replicate C
10
1
0.1
0.01
1E-3
Yt (ft)
0.0
2.0
4.0
6.0
8.0
10.0
Time (min)
ln(Y) = -2.61248 * X + 0.34342
Number of data points used = 40
Coef of determination, R-squared = 0.997


Well PA-26: Post-Demo Replicate C
10
1
0.1
0.01
1E-3
Yt (ft)
0.0
2.0
4.0
6.0
8.0
10.0
Time (min)
ln(Y) = -3.58602 * X + -0.0797991
Number of data points used = 30
Coef of determination, R-squared = 0.982164

Battelle
. . . Putting Technology To Work

CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-26

Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-26	Northing (NAD 83): 1521295
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 11, 2002	Easting (NAD 83): 640145
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2

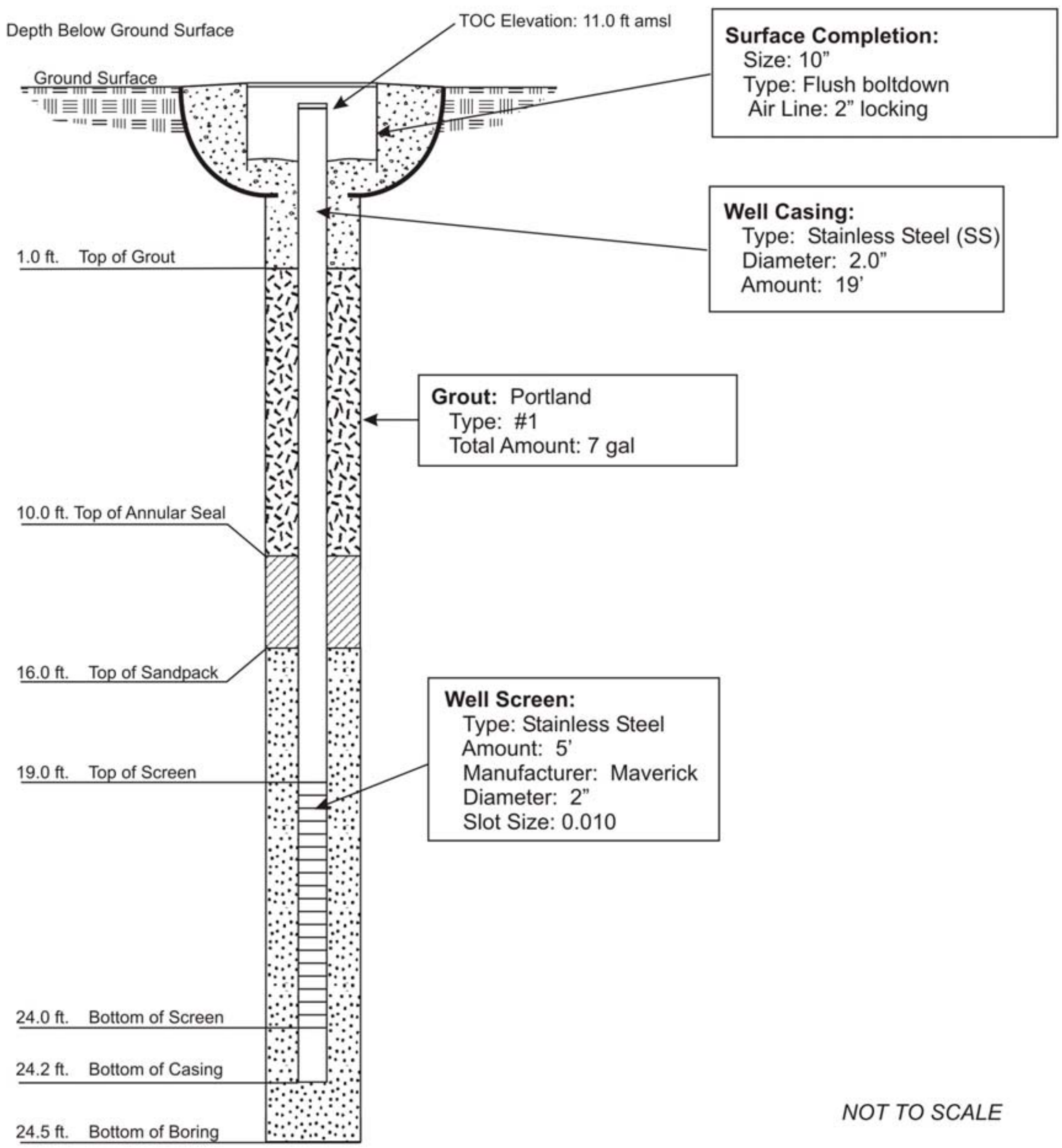


NOT TO SCALE

WCD-PA26.CDR

CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-27S

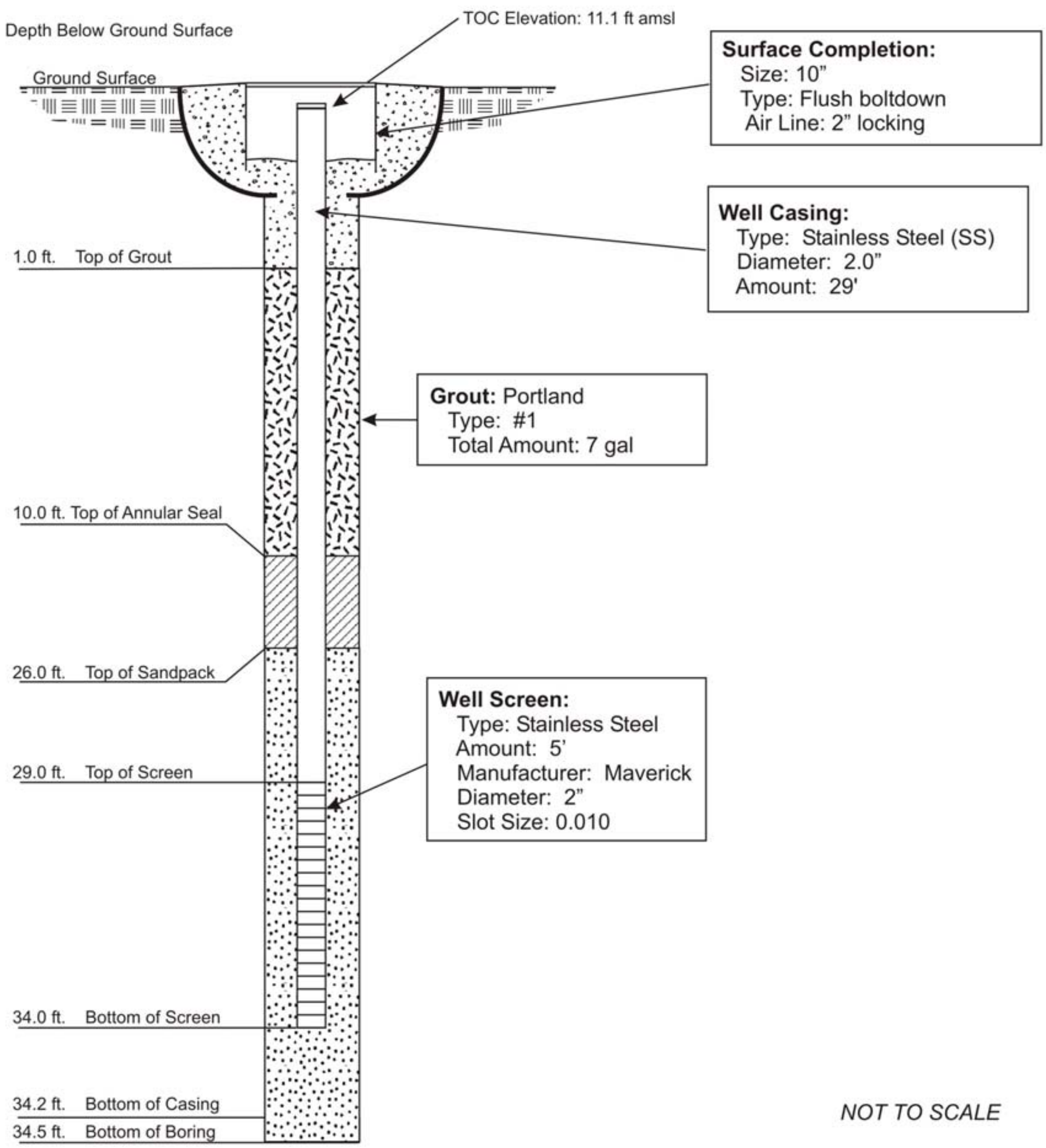
Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-27S	Northing (NAD 83): 1521315
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 12, 2002	Easting (NAD 83): 640149
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2



WCD-PA27-S.CDR

CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-27I

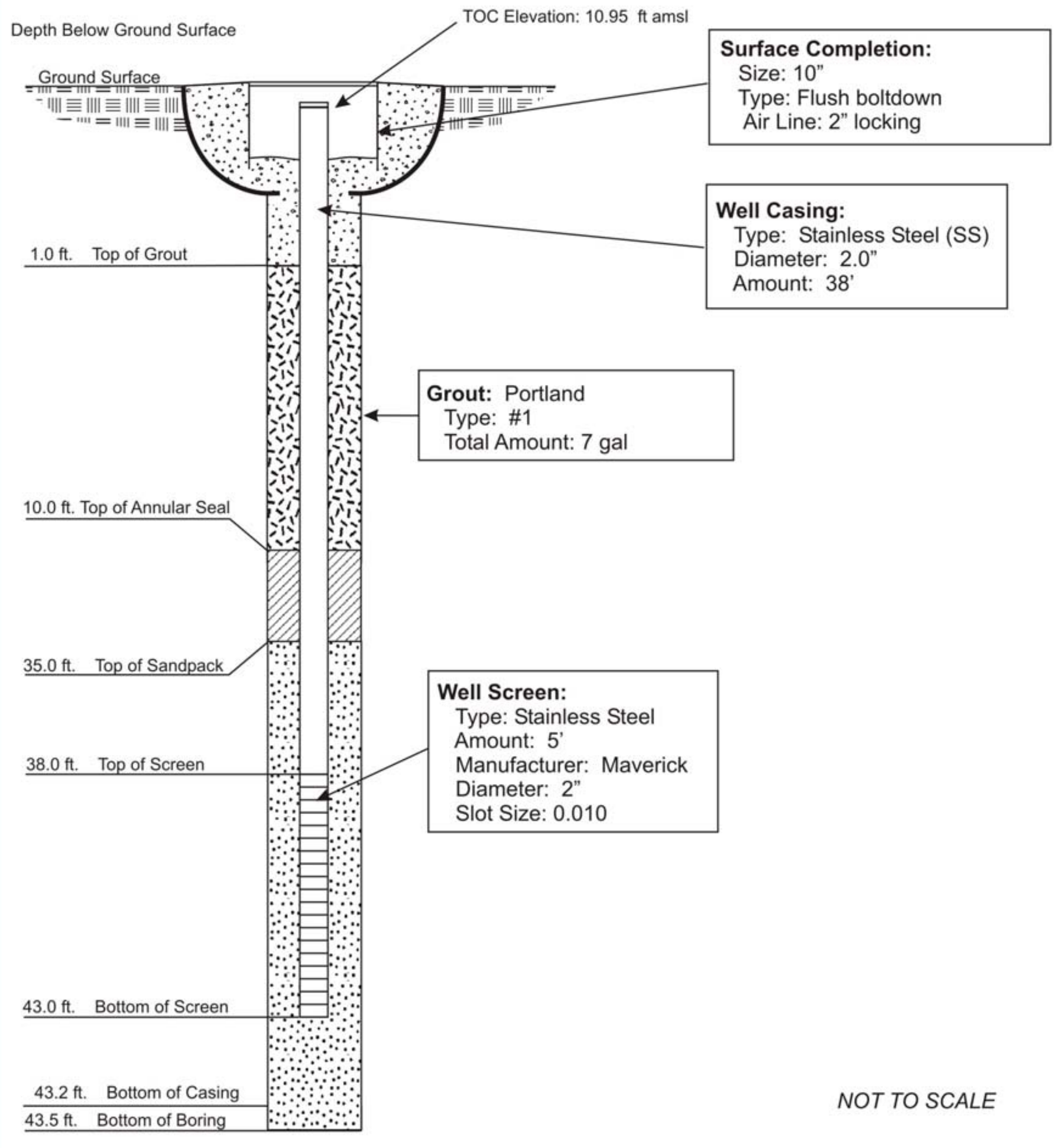
Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-27I	Northing (NAD 83): 1521314
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 12, 2002	Easting (NAD 83): 640151
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2



WCD-PA27-I.CDR

CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-27D

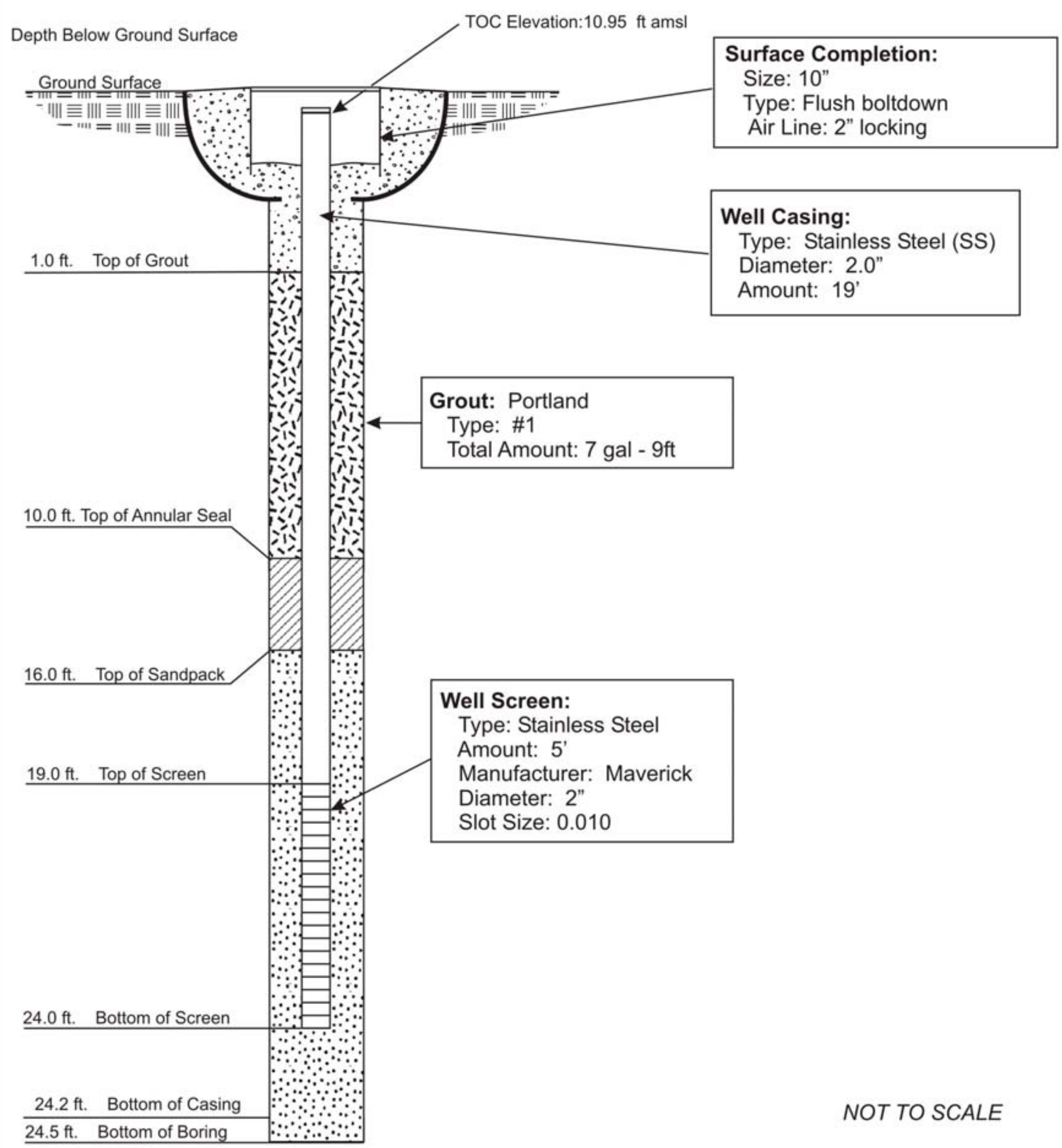
Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-27D	Northing (NAD 83): 1521312
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 12, 2002	Easting (NAD 83): 640154
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2



WCD-PA27-D.CDR

CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-28S

Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-28S	Northing (NAD 83): 1521281
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 20, 2002	Easting (NAD 83): 640139
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2



WCD-PA28-S.CDR

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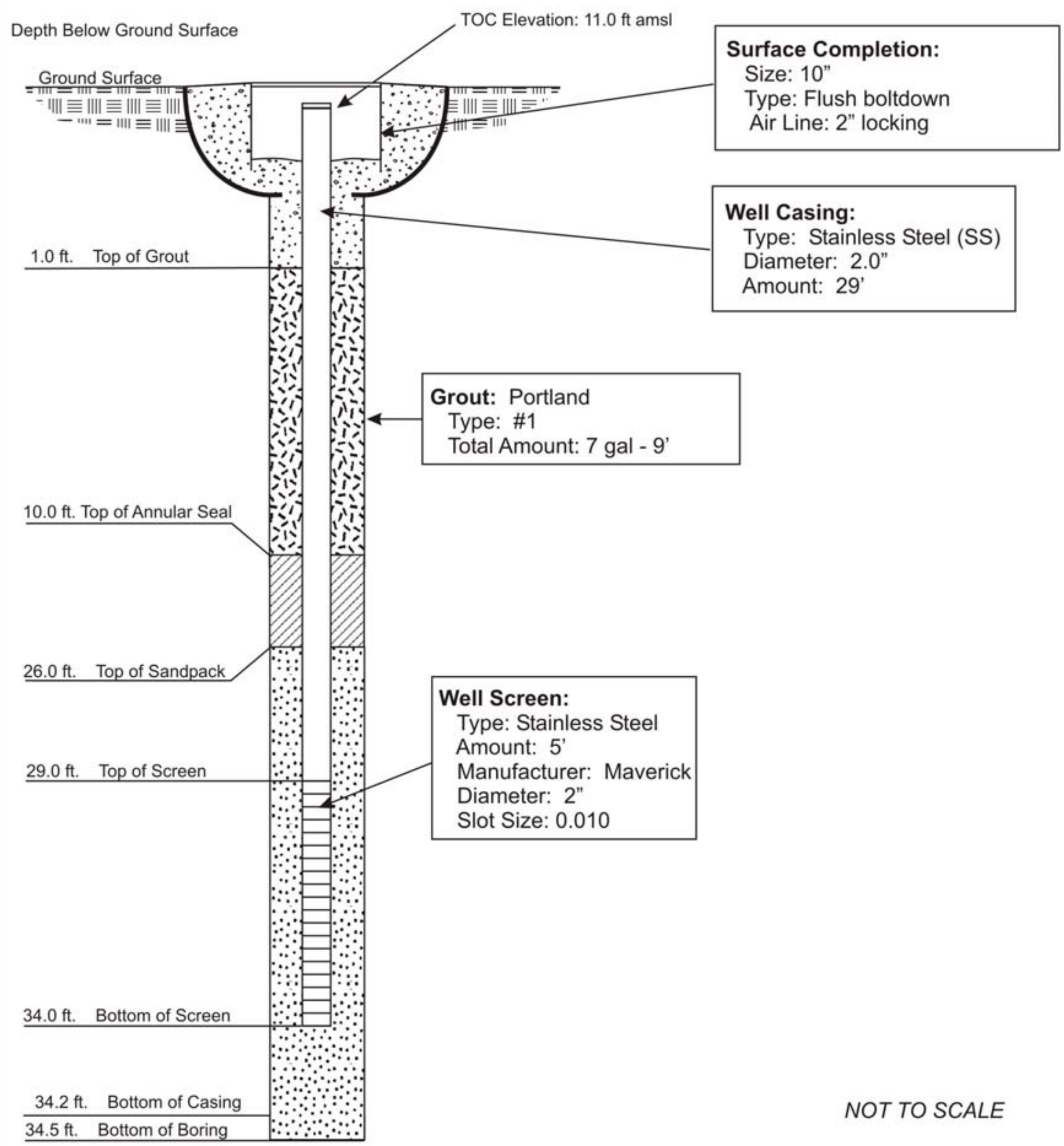
CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-28I

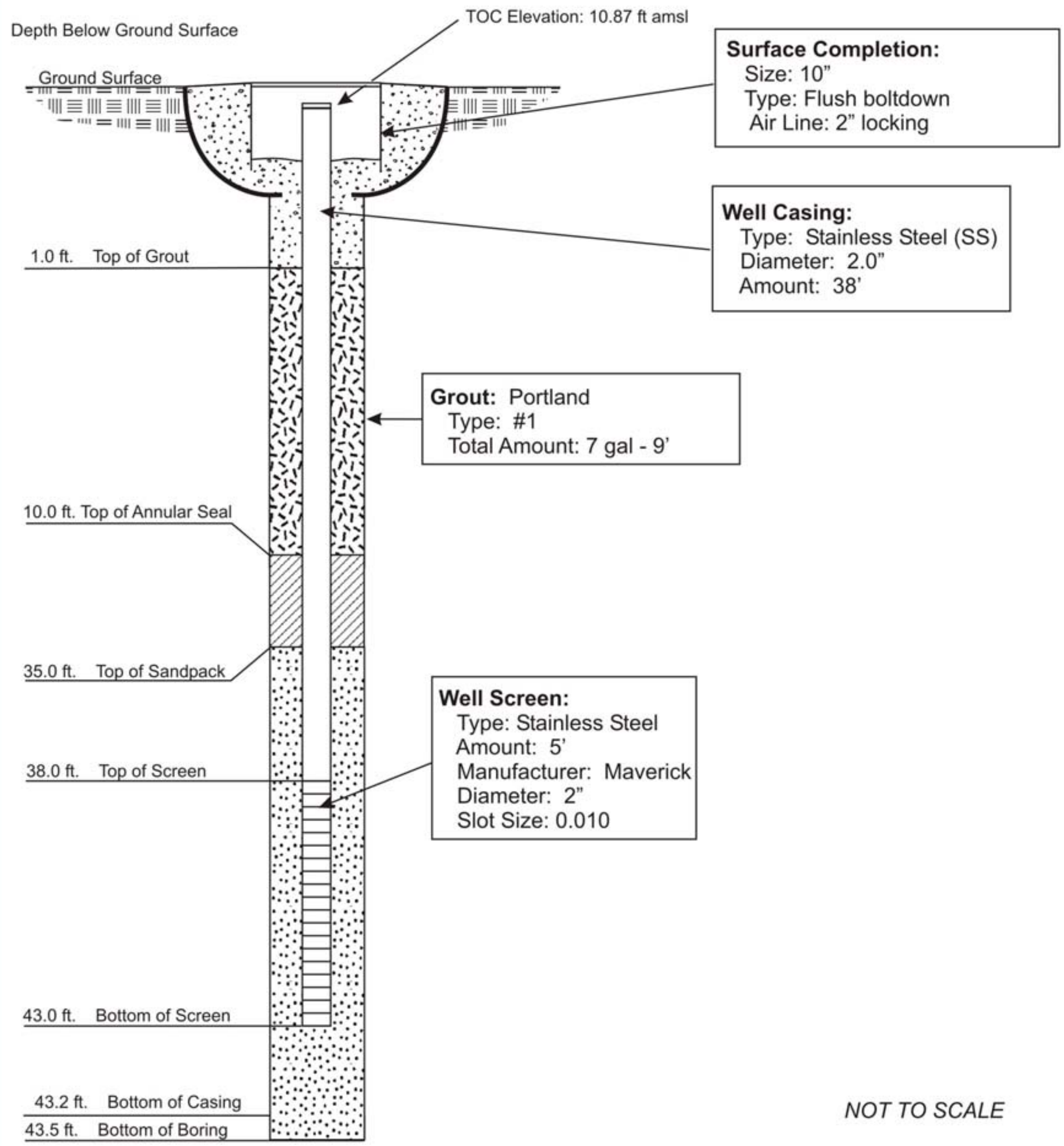
Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-28I	Northing (NAD 83): 1521285
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 7, 2002	Easting (NAD 83): 640133
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2



WCD-PA28-I.CDR

CAPE CANAVERAL
WELL COMPLETION DIAGRAM
PA-28D

Project #: G482010-EPA31	Site: CCAS LC34	Well #: BIO PA-28D	Northing (NAD 83): 1521286
Drilling Contractor: Precision Sampling	Rig Type and Drilling Method: LD-2 Direct Push	Date: Mar 19, 2002	Easting (NAD 83): 640131
Reviewed by: Sam Yoon	Driller: Precision Sampling John Malo	Geologist: MG	Surface Elevation (NAVD 88): 11.2



WCD-PA28-D.CDR

LC34 Coring Logsheet

Date 1/14/02

Boring ID BIO-SB1

Location BIO Plot

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Boring Diameter	2 in	Total Depth	42 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 4 gal
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger fine-med tan sand	0-5	---	SP	---	---
Fine-med tan sand	6-8	BIO-SB1-8	SP	100	8.6
Fine-med tan-gray sand	8-10	BIO-SB1-10	SP	50	75
Fine-med gray sand, trace shell material	10-12	BIO-SB1-12	SP	100	7.5
Fine-med gray sand, trace shell material	12-14	BIO-SB1-14	SP	50	8.6
Fine-med gray sand, trace shell material	14-16	BIO-SB1-16	SP	75	1.6
Fine-med gray sand, trace shell material	16-18	BIO-SB1-18	SP	75	9.0
Fine-med gray sand, trace shell material	18-20	BIO-SB1-20	SP	100	10.6
Fine-med gray sand, trace shell material	20-22	BIO-SB1-22	SP	75	8.3
Fine-med gray sand, trace shell material	22-24	BIO-SB1-24	SP	75	13.6
Silty fine gray sand	24-26	BIO-SB1-26	SP-SM	75	55
Silty fine gray sand	26-28	BIO-SB1-28	SM	75	67
Silty fine gray sand	28-30	BIO-SB1-30	SM	75	75

Logged by: J. Sminchak

Completion Date: 1/14/02

Construction Notes: 4' Macro-core w/ acetate sleeves, rinseate= bio-sb1-rinseate, duplicate= bio-sb1-22dup

LC34 Coring Logsheet Boring ID BIO-SB1

Date 1/14/02 Location BIO Plot

Battelle
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Lithologic Description	**Depth**	**Sample**	**USCS**	**Rec.**	**PID**
Silty gray fine sand, trace shells	30-32	BIO-SB1-32	SM	75	90
Silty gray fine sand, trace shells		BIO-SB1-34	SM	75	105
Silty gray fine sand to coarse shells		BIO-SB1-36	SM-GP	75	70
Coarse shells to silty fine gray sand		BIO-SB1-38	GP-SP	75	19
Silty-clayey fine sand		BIO-SB1-40	SC-SM	50	1.8
Clayey fine sand, low plasticity		BIO-SB1-42	SM-SC	75	0.0
Stop at 42' to avoid penetrating uncontaminated zone					

LC34 Coring Logsheet

Date 1/23/02

Boring ID BIO-SB2

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in		Total Depth	46 ft
Casing Outer Diameter	--- in		Sand Pack	---
Casing Inner Diameter	--- in		Sand Pack Depth	from --- to --- ft
Casing Material	---		Grout Material	Portland 10 gal
Screen Type	---		Grout Depth	from 0 to Depth ft
Screen Slot	---		Surface Completion	Grout flush
Screen Length	--- ft		Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft		Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger fine tan sand	0-5	---	SP	---	---
Fine tan sand to orange-tan sand	6-8	BIO-SB2-8	SP	50	0.6
Orange-tan coarse sand	8-10	BIO-SB2-10	SP	50	1.0
Orange-tan coarse sand	10-12	BIO-SB2-12	SP	75	0.4
Fine-med. gray sand	12-14	BIO-SB2-14	SP	75	8.0
Fine-med. gray sand	14-16	BIO-SB2-16	SP	75	8.0
Fine-med. gray sand	16-18	BIO-SB2-18	SP	75	1.4
Fine gray sand	18-20	BIO-SB2-20	SP	75	0.0
Fine gray sand	20-22	BIO-SB2-22	SP	75	0.9
Fine gray sand	22-24	BIO-SB2-24	SP	75	18.8
Fine gray sand	24-26	BIO-SB2-26	SP-SM	75	26.6
Silty fine sand	26-28	BIO-SB2-28	SM	75	2.6
Silty fine sand	28-30	BIO-SB2-30	SM	75	44.6

Logged by: J. Sminchak

Completion Date: 1/23/02

Construction Notes: 4' Macro-core w/ acetate sleeves, rinseate= bio-sb2-rinseate, duplicate= bio-sb2-14dup

LC34 Coring Logsheet

Boring ID BIO-SB2

Date 1/23/02

Location BIO Plot

Battelle . . . Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Silty fine sand	30-32	BIO-SB2-32	SP-SM	75	18.8
Silty fine sand	32-34	BIO-SB2-34	SP-SM	75	1.8
Silty gray fine sand with coarse shells	34-36	BIO-SB2-36	SM-GM	90	2.7
Silty gray fine sand with coarse shells	36-38	BIO-SB2-38	SM-GM	90	12.2
Silty-clayey fine sand and shells	38-40	BIO-SB2-40	SM-GC	90	30
Silty clayey fine sand and large shell fragments	40-42	BIO-SB2-42	SM-GC	90	0.0
Silty clayey fine sand, 1” clay lense @ 42.3, becoming more shelly	42-44	BIO-SB2-44	SC-SM	100	0.0
Silty clayey fine sand and shells	44-46	BIO-SB2-46	SM-SC	100	0.0
Terminate @ 46’					

LC34 Coring Logsheet	Boring ID BIO-SB3
Date 1/23/02	Location BIO Plot

Battelle ... Putting Technology To Work

Boring Diameter	2 in		Total Depth	46 ft
Casing Outer Diameter	--- in		Sand Pack	---
Casing Inner Diameter	--- in		Sand Pack Depth	from --- to --- ft
Casing Material	---		Grout Material	Portland 15 gal
Screen Type	---		Grout Depth	from 0 to Depth ft
Screen Slot	---		Surface Completion	Grout flush
Screen Length	--- ft		Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft		Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger fine tan sand	0-5	---	SP	---	---
Fine tan sand to orange-tan sand	6-8	BIO-SB3-8	SP	100	0.0
Orange-brown fine sand to fine gray sand	8-10	BIO-SB3-10	SP	100	1.0
Orange-brown fine sand to fine gray sand	10-12	BIO-SB3-12	SP	90	0.5
Fine gray sand	12-14	BIO-SB3-14	SP	90	0.0
Fine gray sand	14-16	BIO-SB3-16	SP	100	3.5
Fine gray sand	16-18	BIO-SB3-18	SP	90	0.0
Fine gray sand	18-20	BIO-SB3-20	SP	90	5.0
Fine gray sand	20-22	BIO-SB3-22	SP	90	2.5
Fine gray sand	22-24	BIO-SB3-24	SP	75	20.1
Fine gray sand, trace silt	24-26	BIO-SB3-26	SP	75	7.6
Silty fine gray sand	26-28	BIO-SB3-28	SP-SM	90	5.7
Silty fine sand	28-30	BIO-SB3-30	SP-SM	90	6.8

Logged by: J. Sminchak

Completion Date: 1/23/02

Construction Notes: 4' Macro-core w/ acetate sleeves, rinseate= bio-sb3-rinseate, duplicate= bio-sb3-18dup

LC34 Coring Logsheet

Date 1/23/02

Boring ID BIO-SB3

Location BIO Plot

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Lithologic Description	**Depth**	**Sample**	**USCS**	**Rec.**	**PID**
Silty fine sand	30-32	BIO-SB3-32	SP-SM	75	8.1
Silty fine sand	32-34	BIO-SB3-34	SP-SM	75	1.2
Silty gray fine sand, trace shells	34-36	BIO-SB3-36	SP-SM	75	0.9
Silty gray fine sand with shells	36-38	BIO-SB3-38	SM-GM	75	0.0
Silty-clayey fine sand and shells, some plasticity	38-40	BIO-SB3-40	SC-GC	100	0.0
Silty clayey fine sand, little plasticity	40-42	BIO-SB3-42	SC-GC	100	0.0
Silty clayey fine sand and shell material	42-44	BIO-SB3-44	SM-SC	90	0.0
Fine gray sand and shell material	44-46	BIO-SB3-46	SP-GP	90	0.0
Terminate @ 46’					

LC34 Coring Logsheet

Boring ID BIO-SB4

Date 1/24/02

Location BIO Plot

Battelle ... Putting Technology To Work

Boring Diameter	2	in		Total Depth	46	ft	
Casing Outer Diameter	---	in		Sand Pack	---		
Casing Inner Diameter	---	in		Sand Pack Depth	from ---	to ---	ft
Casing Material	---			Grout Material	Portland 15 gal		
Screen Type	---			Grout Depth	from 0	to Depth	ft
Screen Slot	---			Surface Completion	Grout flush		
Screen Length	---	ft		Drilling Method	Direct Push Vibra-core		
Screen Depth	from ---	to ---	ft	Driller	Precision		

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger fine tan sand	0-5	---	SP	---	---
Tan-brown fine sand	6-8	BIO-SB4-8	SP	75	0.0
Tan fine-med sand	8-10	BIO-SB4-10	SP	75	0.0
Tan fine-med sand	10-12	BIO-SB4-12	SP	100	0.0
Fine gray sand	12-14	BIO-SB4-14	SP	100	0.4
Fine gray sand	14-16	BIO-SB4-16	SP	90	1.0
Fine gray sand	16-18	BIO-SB4-18	SP	90	0.9
Fine gray sand	18-20	BIO-SB4-20	SP	90	7.1
Fine gray sand	20-22	BIO-SB4-22	SP	90	20.3
Fine gray sand	22-24	BIO-SB4-24	SP	75	30.7
Fine gray sand, trace silt	24-26	BIO-SB4-26	SP	75	45.8
Silty fine gray sand	26-28	BIO-SB4-28	SP-SM	75	5.7
Silty fine gray sand	28-30	BIO-SB4-30	SP-SM	75	3.5

Logged by: J. Sminchak

Completion Date: 1/24/02

Construction Notes: 4' Macro-core w/ acetate sleeves, duplicate= bio-sb4-42dup

LC34 Coring Logsheet Boring ID BIO-SB4

Date 1/24/02 Location BIO Plot

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Lithologic Description	Depth	Sample	USCS	Rec.	PID
Silty fine sand	30-32	BIO-SB4-32	SP-SM	75	5.3
Silty fine sand	32-34	BIO-SB4-34	SP-SM	75	1.2
Silty gray fine sand, trace shells	34-36	BIO-SB4-36	SP-SM	75	NA
Silty gray fine sand with shells	36-38	BIO-SB4-38	SM-GM	75	NA
Silty-clayey fine sand to sandy clay	38-40	BIO-SB4-40	SC-GC	90	NA
Silty clayey fine sand to silty shells and sand	40-42	BIO-SB4-42	SC-GC	90	NA
Silty clayey fine sand to silty shells and sand	42-44	BIO-SB4-44	SM-SC	90	0.0
Coarse shells and sand	44-46	BIO-SB4-46	SP-GP	90	0.0
Terminate @ 46'					

LC34 Coring Logsheet

Boring ID BIO-SB5

Date 2/4/02

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2	in		Total Depth	42	ft	
Casing Outer Diameter	---	in		Sand Pack	---		
Casing Inner Diameter	---	in		Sand Pack Depth	from ---	to ---	ft
Casing Material	---			Grout Material	---		
Screen Type	---			Grout Depth	from 0	to Depth	ft
Screen Slot	---			Surface Completion	Grout flush		
Screen Length	---	ft		Drilling Method	Direct Push Vibra-core		
Screen Depth	from ---	to ---	ft	Driller	Precision		

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger fine tan sand	0-5	---	SP	---	---
White to lt brown sand	6-8	BIO-SB5-8	SP	100	NA
Lt brown fine sand to peach med sand	8-10	BIO-SB5-10	SP	100	NA
Lt brown fine sand to peach med sand	10-12	BIO-SB5-12	SP	75	NA
Peach med. sand to lt gray fine sand	12-14	BIO-SB5-14	SP	75	NA
Lt gray med sand to lt gray sand	14-16	BIO-SB5-16	SP	50	NA
Lt gray fine sand to lt brownish gray med sand	16-18	BIO-SB5-18	SP	100	NA
Lt gray med sand to fine sand	18-20	BIO-SB5-20	SP	75	NA
Lt gray fine sand, trace shells	20-22	BIO-SB5-22	SP	100	NA
Lt gray fine sand, 1" layer of coarse sand to lt gray fine sand	22-24	BIO-SB5-24	SP	75	NA
Lt gray fine sand, trace shells	24-26	BIO-SB5-26	SP	75	NA
Lt. Gray fine sand, trace shells	26-28	BIO-SB5-28	SP-SM	75	NA
Silty gray fine sand, trace shells	28-30	BIO-SB5-30	SP-SM	75	NA

Logged by: L. Cumming

Completion Date: 2/4/02

Construction Notes: 4' Macro-core w/ acetate sleeves, duplicate= bio-sb5-38dup

LC34 Coring Logsheet

Date 2/4/02

Boring ID BIO-SB5

Location BIO Plot

Battelle ... Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Silty gray fine sand, trace shells	30-32	BIO-SB5-32	SM	75	NA
Silty gray fine sand, trace shells	32-34	BIO-SB5-34	SM	100	NA
Silty gray fine sand with shells	34-36	BIO-SB5-36	SM	100	NA
Silty gray fine sand with shells	36-38	BIO-SB5-38	SM	100	NA
Silty sand with coarse sand, some clay	38-40	BIO-SB5-40	SM-SC	100	NA
Silty sand with coarse sand, some clay	40-42	BIO-SB5-42	SM-SC	100	NA
End of core					

LC34 Coring Logsheet

Boring ID BIO-SB6

Date 2/5/02

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in	Total Depth	42 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	---
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	**Depth**	**Sample**	**USCS**	**Rec.**	**PID**
Hand auger fine tan sand	0-5	---	SP	---	---
White to lt brown sand	6-8	BIO-SB6-8	SP	80	9.6
Lt brown fine sand to peach med sand	8-10	BIO-SB6-10	SP	100	7.4
Lt brown fine-med sand	10-12	BIO-SB6-12	SP	100	7.5
Grayish brown-gray fine to med sand, thin layer of shells at top	12-14	BIO-SB6-14	SP	100	22.6
Gray fine-med sand	14-16	BIO-SB6-16	SP	50	44.4
Gray fine-med sand, trace shells	16-18	BIO-SB6-18	SP	100	110
Gray fine-med sand, trace shells, odor	18-20	BIO-SB6-20	SP	50	>2000
Gray fine sand, trace shells, odor	20-22	BIO-SB6-22	SP	100	1720
Gray fine sand, trace shells, strong odor	22-24	BIO-SB6-24	SP	75	2577
Gray fine sand, trace shells, silty, stong odor	24-26	BIO-SB6-26	SP	75	1885
Silty gray fine sand	26-28	BIO-SB6-28	SP-SM	75	3868
Silty gray fine sand	28-30	BIO-SB6-30	SP-SM	75	3413

Logged by: L. Cumming

Completion Date: 2/5/02

Construction Notes: 4' Macro-core w/ acetate sleeves, duplicate= bio-sb6-28dup, bio-sb6-rinseate

LC34 Coring Logsheet

Boring ID BIO-SB6

Date 2/5/02

Location BIO Plot

Battelle ... Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Silty gray fine sand, trace shells	30-32	BIO-SB6-32	SM	100	11375
Silty gray fine sand, trace shells	32-34	BIO-SB6-34	SM	75	3218
Silty gray fine sand with shells	34-36	BIO-SB6-36	SM-GM	100	13032
Silty gray fine sand with shells	36-38	BIO-SB6-38	SM-GM	100	8450
Silty sand with coarse sand, some clay	38-40	BIO-SB6-40	SM-GM	75	4095
Silty sand with coarse sand, some clay	40-42	BIO-SB6-42	GM-GC	100	4875
End of core					

LC34 Coring Logsheet

Boring ID BIO-SB7

Date 2/6/02

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in		Total Depth	42 ft
Casing Outer Diameter	--- in		Sand Pack	---
Casing Inner Diameter	--- in		Sand Pack Depth	from --- to --- ft
Casing Material	---		Grout Material	---
Screen Type	---		Grout Depth	from 0 to Depth ft
Screen Slot	---		Surface Completion	Grout flush
Screen Length	--- ft		Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft		Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger fine tan sand	0-6	---	SP	---	---
White to lt brown fine-med sand	6-8	BIO-SB7-8	SP	90	2.9
Lt brown med-coarse sand to shells to lt brown fine-med. sand	8-10	BIO-SB7-10	SP	100	17.2
Lt brown fine-med sand	10-12	BIO-SB7-12	SP	100	29
Lt gray fine to med sand, little shells	12-14	BIO-SB7-14	SP	100	20.5
Lt gray fine-med sand, trace shells	14-16	BIO-SB7-16	SP	75	55.9
Lt gray fine-med sand, trace shells	16-18	BIO-SB7-18	SP	100	62.4
Lt gray fine-med sand, trace shells	18-20	BIO-SB7-20	SP	75	134
Lt gray fine sand, trace shells, slight odor	20-22	BIO-SB7-22	SP	100	112
Lt gray fine sand, 1” layer of med sand at top	22-24	BIO-SB7-24	SP	75	924
Lt gray med sand, to lt gray fine sand, trace shells, stong odor	24-26	BIO-SB7-26	SP-SM	100	1950
Silty fine gray sand with trace shells	26-28	BIO-SB7-28	SM	90	3250
Silty fine gray sand with trace shells	28-30	BIO-SB7-30	SM	100	6988

Logged by: L. Cumming

Completion Date: 2/6/02

Construction Notes: 4’ Macro-core w/ acetate sleeves, duplicate= bio-sb7-22dup, bio-sb7-rinseate

LC34 Coring Logsheet

Boring ID BIO-SB7

Date 2/6/02

Location BIO Plot

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Lithologic Description	Depth	Sample	USCS	Rec.	PID
Silty gray fine sand, 1" layer med sand	30-32	BIO-SB7-32	SM	60	2275
Silty gray fine-med sand, trace shells	32-34	BIO-SB7-34	SM	100	1982
Silty gray fine sand with med-coarse shells	34-36	BIO-SB7-36	SM	100	6500
Silty fine sand with med-coarse shells, little shells in bottom 2"	36-38	BIO-SB7-38	SM	100	4072
Silty fine sand with med-coarse shells	38-40	BIO-SB7-40	SM-GM	100	3250
Silty fine sand with med-coarse shells	40-42	BIO-SB7-42	SM	100	815
End of core					

LC34 Coring Logsheet

Boring ID: BIO-WP1

Date: 1/21/02

Location: BIO Plot

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Boring Diameter	2 in	Total Depth	38 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 10 gal
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger tan fine sand	0-5	-	-	-	-
Direct push	5-15	-	-	-	-
Chloride sample ~11:30	15	Bio-wp1-15	-	500 ml	-
Direct push	15-20	-	-	-	-
Chloride sample ~14:30	20	Bio-wp1-20	-	500 ml	-
Direct push	20-30	-	-	-	-
Chloride sample ~15:00	30	Bio-wp1-30	-	500 ml	-
Direct push	30-36	-	-	-	-
Chloride sample ~15:30, silty low flow, pull up 1' for better flow	36	Bio-wp1-36	-	500 ml	-
Direct push	36-38	-	-	-	-
Chloride sample ~17:00	38	Bio-wp1-38	-	500 ml	-

Logged by: J. Sminchak

Completion Date: 1/21/02

Construction Notes:

waterloo profiler, purge 700 ml/sample

LC34 Coring Logsheet

Date 1/22/02

Boring ID BIO-WP2

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2	in	Total Depth		38	ft
Casing Outer Diameter	---	in	Sand Pack		---	
Casing Inner Diameter	---	in	Sand Pack Depth	from --- to ---		ft
Casing Material	---		Grout Material		Portland 10 gal	
Screen Type	---		Grout Depth	from 0 to Depth		ft
Screen Slot	---		Surface Completion		Grout flush	
Screen Length	---	ft	Drilling Method		Direct Push	
Screen Depth	from --- to ---	ft	Driller		Precision	

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger tan fine sand	0-5	-	-	-	-
Direct push	5-15	-	-	-	-
Chloride sample	15	Bio-wp2-15	-	500 ml	-
Direct push	15-20	-	-	-	-
Chloride sample	20	Bio-wp2-20	-	500 ml	-
Direct push	20-30	-	-	-	-
Chloride sample	30	Bio-wp2-30	-	500 ml	-
Direct push	30-36	-	-	-	-
Chloride sample, silty low flow	36	Bio-wp2-36	-	500 ml	-
Direct push	36-38	-	-	-	-
Chloride sample	38	Bio-wp2-38	-	500 ml	-

Logged by: J. Sminchak

Completion Date: 1/22/02

Construction Notes:

waterloo profiler, purge 700 ml/sample

LC34 Coring Logsheet

Date 6/17/03

Boring ID BIO-SB202

Location BIO Plot

Battelle ... Putting Technology To Work

Boring Diameter	2 in	Total Depth	42 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 6 gal.
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger 0-4 ft. tan sand	0-4	none	SP	---	---
Light gray medium sand	4-6	none	SP	50	---
Top 2 " Light gray medium sand, ~6-7 ft orange-brown med. sand, 7-8 orange-brown coarse sand	6-8	BIO-SB202-8	SP	100	80.4 104
8-9 ft no recovery 9-10 ft light brown-orange medium sand	8-10	BIO-SB202-10	SP	50	80
10-11 ft light brown-orange medium sand to coarse sand 11-12 ft gray fine sand	10-12	BIO-SB202-12	SP	100	85 140
12-13 ft brown coarse sand with trace shells 13-14 ft gray fine sand	12-14	BIO-SB202-14	SP	100	5.5
14-16 gray fine sand, bio odor?	14-16	BIO-SB202-16	SP	100	8.9
16-16.5 ft brown coarse sand 16.5-18 ft gray medium-fine sand	16-18	BIO-SB202-18	SP	95	5.5
18-20 ft gray fine sand	18-20	BIO-SB202-20	SP	100	3.9
20-21 ft no recovery 21-22 ft gray medium fine sand	20-22	BIO-SB202-22	SP	50	28.2
22-24 ft gray fine sand (bio odor?)	22-24	BIO-SB202-24	SP	100	26.3
24-25 ft no recovery 25-26 ft gray fine sand	24-26	BIO-SB202-26	SP	50	56
26-27.5 ft gray silty fine sand 27.5-28 ft coarse gray silty sand with shells (2") gray silty fine sand	26-28	BIO-SB202-28	SP-SM	100	75 94

Logged by: M. Gaberell

Completion Date: 6/17/03

Construction Notes: 4' Macro-core acetate sleeves, rinseate = BIO-SB202-Rinsate, Dup = BIO-SB202-20DUP

LC34 Coring Logsheet

Boring ID BIO-SB202

Date 6/17/03

Location BIO Plot

Battelle ... Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
28-29 ft no recovery 29-30 ft gray silty fine sand	28-30	BIO-SB202-30	SP-SM	50	362
30-31 ft gray silty fine sand 31-32 ft gray silty fine sand with trace shells	30-32	BIO-SB202-32	SP-SM	100	953
No recovery	32-34	BIO-SB202-34	---	0	---
Silty fine gray sand with trace shells	34-36	BIO-SB202-36	SM-SP	100	4492 1005
No recovery	36-38	BIO-SB202-38	---	0	---
Gray silt with shells	38-40	BIO-SB202-40	SM-GM	100	1192
Gray clayey silt with trace shells	40-42	BIO-SB202-42	SM-SC	100	702
-stop at 42’ to avoid penetrating confining layer-					

LC34 Coring Logsheet

Date 6/18/03

Boring ID BIO-SB205

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in	Total Depth	45 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 6 gal.
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger 0-6 ft. tan sand	0-6	none	SP	---	---
6.5-7 ft light gray medium coarse sand 7-8 ft orange brown medium sand	6-8	BIO-SB205-8	SP	75	0
8-9 ft orange brown medium sand 9-10 ft orange brown coarse sand to brown med sand	8-10	BIO-SB205-10	SP	100	262 545
Brown medium sand	10-12	BIO-SB205-12	SP	75	0
12-13 ft gray medium sand 13-14 ft gray med-coarse sand, 3” coarse sand at 13.5 ft.	12-14	BIO-SB205-14	SP	100	472
14-15 ft brown medium sand 15-16 ft gray coarse sand with trace shells	14-16	BIO-SB205-16	SP	100	152
16-17 ft dark gray coarse sand with shells, 2” band of dk gray at 16’ 17-18 gray fine sand	16-18	BIO-SB205-18	SP	100	252
<30% recovery, combined approx 2” of soil with SB205-22	18-20	BIO-SB205-20	---	<30	---
20-22 ft gray fine sand	20-22	BIO-SB205-22	SP	100	52 200
<30% recovery, combined approx 2” of soil with SB205-26	22-24	BIO-SB205-24	---	<30	---
24-25.5 ft gray fine sand 25.5-26 ft gray silty fine sand (strong odor, not TCE, maybe bio?)	24-26	BIO-SB205-26	SP	100	396
gray silty fine sand	26-28	BIO-SB205-28	SP-SM	60	0.0
28-29 ft gray silty fine sand 29-30 ft gray silty sand with trace shells	28-30	BIO-SB205-30	SP-SM	100	>9999

Logged by: M. Gaberell

Completion Date: 6/18/03

Construction Notes: 4’ Macro-core acetate sleeves, rinseate = BIO-SB205-Rinsate, Dup = BIO-SB202-40DUP

LC34 Coring Logsheet

Boring ID BIO-SB205

Date 6/18/03

Location BIO Plot

Battelle
. . . Putting Technology To Work

Lithologic Description	**Depth**	**Sample**	**USCS**	**Rec.**	**PID**
30-31 ft no recovery 31-32 ft gray silty fine sand	30-32	BIO-SB202-32	SP-SM	50	>9999
32-33 ft gray silty fine sand with trace shells 33-34 ft gray silty fine sand with coarse shells	32-34	BIO-SB202-34	SM-GM	100	>9999
No recovery	34-36	BIO-SB202-36	---	0	---
36-37.5 ft gray silty fine sand with trace shells 37.5-38 ft gray silty fine sand	36-38	BIO-SB202-38	SM-GM	100	>9999
38-40 ft very wet, gray silty fine sand with many shells, tce odor	38-40	BIO-SB202-40	SM-GC	100	>9999
40-42 ft gray silty fine sand with many shells, very wet, tce odor	40-42	BIO-SB202-42	SM-GC	100	>9999
42-45 ft gray silty fine sand with significant shells and noticeable clay at bottom	42-45	BIO-SB202-45	SM-SC	100	>9999
End of core					

LC34 Coring Logsheet

Boring ID BIO-SB206

Date 6/19/03

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in	Total Depth	40 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 6 gal.
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger 0-4 ft. tan sand	0-4	none	SP	---	---
Not sampled or logged	4-6	none	---	---	---
6-6.5 ft Light brown medium coarse sand 6.5-8 ft Brown-orange medium sand	6-8	BIO-SB206-8	SP	100	0
<20% recovery sampled 2" of soil with BIO-sb206-12 sample	8-10	BIO-SB206-10	SP	>20	---
10-11 ft brown-orange medium coarse to dk br med-coarse sand 11-12 ft light brown medium sand to coarse medium sand, trc shells	10-12	BIO-SB206-12	SP	100	54.7
Brown medium-coarse sand	12-14	BIO-SB206-14	SP	90	74.9
14-14.5 ft Gray medium coarse sand 14.5-16 ft Dark gray coarse sand with trace shells, apricot odor	14-16	BIO-SB206-16	SP	100	62.9
No recovery	16-18	---	---	0	---
18-19.5 ft Gray medium-coarse sand 19.5-20 ft Gray medium sand, apricot odor	18-20	BIO-SB206-20	SP	100	0.0
20-21 ft gray medium sand to dark gray coarse sand with shells 21-22 ft dark gray medium fine sand with shells, apricot odor	20-22	BIO-SB206-22	SP	100	39.2
No recovery	22-24	---	SP	0	---
Gray fine sand, apricot odor	24-26	BIO-SB206-26	SP	75	88.2
Gray fine sand, apricot odor	26-28	BIO-SB206-28	SP-SM	100	161

Logged by: M. Gaberell

Completion Date: 6/19/03

Construction Notes: 4' Macro-core acetate sleeves, rinseate = BIO-SB206-Rinsate, Dup = BIO-SB206-22DUP

LC34 Coring Logsheet

Boring ID BIO-SB206

Date 6/19/03

Location BIO Plot

Battelle ... Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Gray fine sand, apricot odor	28-30	BIO-SB206-30	SP-SM	100	362
30-31.5 ft gray silty fine sand 31.5-32 ft gray silty fine sand with trace shells, apricot odor	30-32	BIO-SB206-32	SP-SM	100	NA
Gray silty fine sand, very wet	32-34	BIO-SB206-34	SP-SM	90	NA
Gray silty fine sand, with trace shells, very wet	34-36	BIO-SB206-36	SP-SM	100	NA
Gray silty fine sand with shells, very wet	36-38	BIO-SB206-38	SP-SM	100	NA
Gray clayey sand with shells, very wet, bottom 2” clay	38-40	BIO-SB206-40	SM-SC	100	NA
-stop at 40’-					

LC34 Coring Logsheet

Date 6/17/03

Boring ID BIO-SB207

Location BIO Plot

Battelle ... Putting Technology To Work

Boring Diameter	2 in	Total Depth	40 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 6 gal.
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Hand auger 0-4 ft. tan sand	0-4	none	SP	---	---
Brown coarse sand	4-6	none	SP	---	---
Brown orange medium coarse sand	6-8	BIO-SB207-8	SP	100	0
<20% recovery	8-10	---	---	<20	---
Brown-orange coarse sand, dark brown medium sand (2" band) Tan medium sand	10-12	BIO-SB207-12	SP	100	0
Tan medium-coarse sand	12-14	BIO-SB207-14	SP	100	0
Gray medium-coarse sand	14-16	BIO-SB207-16	SP	100	0
No recovery	16-18	---	---	0	---
18-19.5 ft gray medium sand, gray coarse sand (3" band), gray fine sand	18-20	BIO-SB207-20	SP	100	0
Gray medium to fine sand, very wet	20-22	BIO-SB207-22	SP	90	0
Gray medium-fine sand, very wet	22-24	BIO-SB207-24	SP	100	0
<20% recovery, sampled 2" with BIO-sb207-28	24-26	---	---	<20%	---
26-26.4 ft gray medium-fine sand 26.4-28 ft gray medium fine sand with trace shells	26-28	BIO-SB207-28	SP	100	2925 1795

Logged by: M. Gaberell

Completion Date: 6/20/03

Construction Notes: 4' Macro-core acetate sleeves, rinseate = BIO-SB207-Rinsate, Dup = BIO-SB207-28DUP

LC34 Coring Logsheet Boring ID BIO-SB207

Date 6/20/03 Location BIO Plot

Battelle . . . Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Gray silty fine sand	28-30	BIO-SB202-30	SP-SM	90	2743
Gray silty fine sand	30-32	BIO-SB202-32	SP-SM	100	3813
Gray silty fine sand	32-34	BIO-SB202-34	SP-SM	100	2892
Gray silty fine sand, very wet	34-36	BIO-SB202-36	SM-SP	100	336
36-37 ft gray silty fine sand, very wet 37-38 ft gray silty fine sand with trace shells, very wet	36-38	BIO-SB202-38	SP-SM	100	NA
Gray silty fine sand with shells, significant clay visible in bottom 2 inches, very wet	38-40	BIO-SB202-40	SP-SM	60	NA
-stop at 40'-					

LC34 Coring Logsheet

Boring ID BIO-SB210

Date 6/18/03

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in		Total Depth		30 ft
Casing Outer Diameter	--- in		Sand Pack		---
Casing Inner Diameter	--- in		Sand Pack Depth	from --- to --- ft	
Casing Material	---		Grout Material		Portland
Screen Type	---		Grout Depth	from 0 to Depth ft	
Screen Slot	---		Surface Completion		Grout flush
Screen Length	--- ft		Drilling Method		Direct Push Vibra-core
Screen Depth	from --- to --- ft		Driller		Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Not sampled	0-12	none	---	---	---
No recovery	12-13	---	--	0	---
No recovery	13-14	---	--	0	---
Brown coarse sand	14-15	BIO-SB210-15	SP	100	0
Gray medium sand, 1” gray coarse sand band at 15.5 ft	15-16	BIO-SB210-16	SP	100	0
No recovery	16-17	---	--	0	---
No recovery	17-18	---	--	0	---
Fine gray sand	18-19	BIO-SB210-19	SP	100	0.0
19-19.5 ft Gray fine sand 19.5-20 ft Coarse gray sand with trace shells	19-20	BIO-SB210-20	SP	100	0.0
No recovery	20-21	---	--	0	---
Gray coarse sand with shells	21-22	BIO-SB210-22	SP	100	0.0
Gray silty fine sand with trace shells	22-23	BIO-SB210-23	SP-SM	100	0.0
Gray fine sand with coarse shells	23-24	BIO-SB210-24	SP-GM	100	0

Logged by: M. Gaberell

Completion Date: 6/18/03

Construction Notes: 4’ Macro-core acetate sleeves, BIO-sb210-20dup

LC34 Coring Logsheet

Date 6/18/03

Boring ID BIO-SB210

Location BIO Plot

Battelle . . . Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
No recovery	24-25	---	---	0	---
Gray medium fine sand with trace shells	25-26	BIO-SB210-26	SP	50	0.0
Gray fine sand	26-27	BIO-SB210-27	SP	100	0.0
Gray fine sand	27-28	BIO-SB210-28	SP	100	0.0
Gray fine sand, TCE odor	28-29	BIO-SB210-29	SP	100	1427
Gray fine sand, TCE odor	29-30	BIO-SB210-30	SP	100	>9999
-end of core @ 30'-					

LC34 Coring Logsheet Boring ID BIO-SB211

Date 6/19/03 Location BIO Plot

Boring Diameter	2 in	Total Depth	30 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland 6 gal.
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
0-12 ft no sample, not logged	0-12	none	---	---	---
No recovery	12-13	none	---	0	---
No recovery	13-14	none	---	0	---
Brown medium coarse sand	14-15	BIO-SB211-15	SP	100	57.1
3” brown medium coarse sand gray medium coarse sand to medium sand	15-16	BIO-SB211-16	SP	100	63.5
No recovery	16-17	BIO-SB211-17	---	---	---
Gray medium sand, apricot odor	17-18	BIO-SB211-18	SP	100	54.2
Gray medium sand, apricot odor	18-19	BIO-SB211-19	SP	100	38.1
Gray medium sand, apricot odor	19-20	BIO-SB211-20	SP	100	69.2
No recovery	20-21	BIO-SB211-21	---	0	---
Gray coarse sand, gray fine sand, apricot odor	21-22	BIO-SB211-22	SP	100	223
Gray medium fine sand, apricot odor	22-23	BIO-SB211-23	SP	100	125
Gray medium fine sand, apricot odor	23-24	BIO-SB211-24	SP	100	49.5

Logged by: M. Gaberell

Completion Date: 6/19/03

Construction Notes: 4’ Macro-core acetate sleeves, BIO-sb211-24dup

LC34 Coring Logsheet

Date 6/19/03

Boring ID BIO-SB211

Location BIO Plot

Battelle
. . . Putting Technology To Work

Lithologic Description	Depth	Sample	USCS	Rec.	PID
No recovery	24-25	---	---	0	---
No recovery	25-26	---	---	0	---
Gray fine sand, apricot odor	26-27	BIO-SB211-27	SP	10	71.9
Gray fine sand, apricot odor	27-28	BIO-SB211-28	SP	100	164
Gray fine sand, apricot odor	28-29	BIO-SB211-29	SP	100	210
Gray silty fine sand, apricot odor	29-30	BIO-SB211-30	SP-SM	100	137
-End of core @ 30'-					

LC34 Coring Logsheet

Boring ID BIO-WP201

Date 6/20/03

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in		Total Depth	38 ft	
Casing Outer Diameter	--- in		Sand Pack	---	
Casing Inner Diameter	--- in		Sand Pack Depth	from --- to --- ft	
Casing Material	---		Grout Material	Portland	
Screen Type	---		Grout Depth	from 0 to Depth ft	
Screen Slot	---		Surface Completion	Grout flush	
Screen Length	--- ft		Drilling Method	Direct Push Vibra-core	
Screen Depth	from --- to --- ft		Driller	Precision	

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Waterloo Profile					
Collect Sample BIO-WP-201-18 @15:04					
Collect Sample BIO-WP-201-24 @15:31					
Collect Sample BIO-WP-201-33 @16:00					
Collect Sample BIO-WP-201-38 @16:16					

Logged by: M. Gaberell

Completion Date: 6/20/03

Construction Notes: 3 x 40 ml VOAs for chloride analysis

LC34 Coring Logsheet

Boring ID BIO-WP202

Date 6/21/03

Location BIO Plot

Battelle . . . Putting Technology To Work

Boring Diameter	2 in	Total Depth	38 ft
Casing Outer Diameter	--- in	Sand Pack	---
Casing Inner Diameter	--- in	Sand Pack Depth	from --- to --- ft
Casing Material	---	Grout Material	Portland
Screen Type	---	Grout Depth	from 0 to Depth ft
Screen Slot	---	Surface Completion	Grout flush
Screen Length	--- ft	Drilling Method	Direct Push Vibra-core
Screen Depth	from --- to --- ft	Driller	Precision

Lithologic Description	Depth	Sample	USCS	Rec.	PID
Waterloo Profile					
Collect Sample BIO-WP-202-18 @08:25					
Collect Sample BIO-WP-202-24 @08:39					
Collect Sample BIO-WP-202-33 @08:57					
Collect Sample BIO-WP-202-38 @10:00					

Logged by: M. Gaberell

Completion Date: 6/21/03

Construction Notes: 3 x 40 ml VOAs for chloride analysis

Appendix C

CVOC Measurements

Table C-1a. CVOC Monitoring Results of the Biostimulation and Bioaugmentation Demonstration

	TCE (µg/L)				*cis* -1,2-DCE (µg/L)			
Well ID	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**
BIO Plot Well								
PA-26	**1,220,000**	7,460	13,800	239	31,600	94,700	19,400	780
PA-26-DUP	NA	7,180	NA	158	NA	85,600	NA	757
BIO Perimeter Wells								
PA-27S	659,000	347,000	379,000	168,000	67,300	16,900	186,000	219,000
PA-27I	565,000	690,000	906,000	**1,110,000**	41,300	7,030	5,430	7,820
PA-27D	394,000	665,000	**1,020,000**	919,000	64,100	8,080	6,180	8,030
PA-28S	801,000	69,200	68,200	67,500	28,100	95,100	162,000	136,000
PA-28S-DUP	NA	NA	55,200	NA	NA	NA	154,000	NA
PA-28I	620,000	512,000	838,000	912,000	87,600	88,200	100,000	225,000
PA-28D	79,600	89,200	46,700	4,730	169,000	178,000	98,200	179,000
Injection & Extraction Wells								
BIW	NA	117,000	95,200	NA	NA	30,100	53,000	NA
BIW-2	105,000	117,000	93,000	<20	45,700	30,000	54,300	11,800
BEW	NA	109,000	946,000	NA	NA	29,300	56,800	NA
BEW-2	111,000	5,750	79,600	227	55,600	3,360	65,400	19,800

	trans -1,2-DCE (µg/L)				Vinyl chloride (µg/L)			
Well ID	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**
BIO Plot Well								
PA-26	<1,000	350	419	436	<1,000	3,430	103,000	8,040
PA-26-DUP	NA	424	NA	427	NA	4,050	NA	6,840
BIO Perimeter Wells								
PA-27S	300 J	320 J	420 J	822	520	100 J	28,700	52,800
PA-27I	340 J	50 J	<1,000	<1,000	<500	200 J	230 J	<1,000
PA-27D	240 J	<500	<1,000	<1,000	<500	<500	<1,000	<1,000
PA-28S	170 J	321	480	360 J	<1,000	7,420	55,800	37,200
PA-28S-DUP	NA	NA	512	NA	NA	NA	55,000	NA
PA-28I	280 J	270 J	290 J	820 J	<500	140 J	160 J	880 J
PA-28D	410	813	362	764	34 J	134	1,510	8,550
Injection & Extraction Wells								
BIW	NA	127	333	NA	NA	185	17,100	NA
BIW-2	370	139	307	428	161	179	16,400	30,900
BEW	NA	158	345	NA	NA	224	18,200	NA
BEW-2	206	24.4	409	464	325	69	17,600	44,900

NA: Not available.
J: Estimated value, below reporting limit.
Shading denotes that the level is exceeding or close to the saturation point (i.e. free-phase) at TCE solubility of 1,100 mg/L.
Pre-Demo: March 2002.
Post-Demo: June 2003.
BIW and BEW: BIW and BEW samples were collected from the combined ports.
S: designates shallow wells with the screen depths located in Upper Sand Unit.
I: desginates for intermediate wells with the screen depths located in Middle Fine-Grained Unit.
D: designates deep wells with the screen depths located in Lower Sand Unit.

Table C-1b. CVOC Monitoring Results of the Biostimulation and Bioaugmentation Demonstration

	TCE (mmole/L)				*cis* -1,2-DCE (mmole/L)			
Well ID	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**
BIO Plot Well								
PA-26	**9.31**	0.06	0.11	0.00	0.33	0.98	0.20	0.01
PA-26-DUP	NA	0.05	NA	0.00	NA	0.88	NA	0.01
BIO Perimeter Wells								
PA-27S	5.03	2.65	2.89	1.28	0.69	0.17	1.92	2.26
PA-27I	4.31	5.27	6.92	**8.47**	0.43	0.07	0.06	0.08
PA-27D	3.01	5.08	**7.79**	7.02	0.66	0.08	0.06	0.08
PA-28S	6.11	0.53	0.52	0.52	0.29	0.98	1.67	1.40
PA-28S-DUP	NA	NA	0.42	NA	NA	NA	1.59	NA
PA-28I	4.73	3.91	6.40	6.96	0.90	0.91	1.03	2.32
PA-28D	0.61	0.68	0.36	0.04	1.74	1.84	1.01	1.85
Injection & Extraction Wells								
BIW	NA	0.89	0.73	NA	NA	0.31	0.55	NA
BIW-2	0.80	0.89	0.71	<0.01	0.47	0.31	0.56	0.12
BEW	NA	0.83	7.22	NA	NA	0.30	0.59	NA
BEW-2	0.85	0.04	0.61	0.00	0.57	0.03	0.67	0.20

	trans -1,2-DCE (mmole/L)				Vinyl chloride (mmole/L)			
Well ID	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**	**Pre-Demo**	**Dec 2002**	**Mar 2003**	**Post-Demo**
BIO Plot Well								
PA-26	<0.02	0.01	0.01	0.01	<0.02	0.06	1.64	0.13
PA-26-DUP	NA	0.01	NA	0.01	NA	0.07	NA	0.11
BIO Perimeter Wells								
PA-27S	0.01	0.01	0.01	0.01	0.01	0.01	0.46	0.84
PA-27I	0.01	0.01	<0.02	<0.02	<0.02	0.01	0.01	<0.02
PA-27D	0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
PA-28S	0.01	0.01	0.01	0.01	<0.02	0.12	0.89	0.60
PA-28S-DUP	NA	NA	0.01	NA	NA	NA	0.88	NA
PA-28I	0.01	0.01	0.01	0.01	<0.02	0.01	0.01	0.02
PA-28D	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.14
Injection & Extraction Wells								
BIW	NA	0.01	0.01	NA	NA	0.01	0.28	NA
BIW-2	0.01	0.01	0.01	0.01	0.01	0.01	0.27	0.50
BEW	NA	0.01	0.01	NA	NA	0.01	0.29	NA
BEW-2	0.01	0.01	0.01	0.01	0.01	0.01	0.28	0.72

NA: Not available.
J: Estimated value, below reporting limit.
Shading denotes that the level is exceeding or close to the saturation point (i.e. free-phase) at or near TCE solubility of 1,100 mg/L (8.40 m mole/L).
Pre-Demo: March 2002.
Post-Demo: June 2003.
BIW and BEW: BIW and BEW samples were collected from the combined ports.
S: designates shallow wells with the screen depths located in Upper Sand Unit.
I: desginates for intermediate wells with the screen depths located in Middle Fine-Grained Unit.
D: designates deep wells with the screen depths located in Lower Sand Unit.

Table C-2. Summary of CVOC Results in Soil for Pre-demonstration Monitoring in Bioaugmentation Plot

Sample ID	Sample Depth (ft) Top Depth	Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (µg/L)	TCE Results in Dry Soil (mg/Kg)	*cis* -1,2-DCE Results in MeOH (µg/L)	*cis* -1,2-DCE Results in Dry Soil (mg/Kg)	*trans* -1,2-DCE Results in MeOH (µg/L)	*trans* -1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (µg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-1-8 (SS)	6	8	1/14/2002	189	104	94	180	0	75J	0	<100	ND	<100	ND
BIO-SB-1-10	8	10	1/14/2002	194	131	110	844	2	556	1	<100	ND	<100	ND
BIO-SB-1-12	10	12	1/14/2002	191	146	131	488	1	244	0	<100	ND	<100	ND
BIO-SB-1-14	12	14	1/14/2002	192	147	129	6,340	13	4,660	9	<100	ND	49J	0
BIO-SB-1-16	14	16	1/14/2002	195	78	71	3,650	13	2,000	7	<100	ND	18J	0
BIO-SB-1-18	16	18	1/14/2002	191	117	111	2,650	6	2,340	5	<100	ND	37J	0
BIO-SB-1-20	18	20	1/14/2002	190	143	127	4,000	8	7,080	14	24J	0	171	0
BIO-SB-1-22	20	22	1/14/2002	191	88	77	6,500	21	5,830	19	23J	0	117	0
BIO-SB-1-22-DUP	20	22	1/14/2002	193	79	69	4,090	15	4,630	17	13J	0	100	0
BIO-SB-1-24	22	24	1/14/2002	190	100	86	43,200	128	2,660	8	<100	ND	<100	ND
BIO-SB-1-26	24	26	1/14/2002	193	73	62	64,300	**265**	2,760	11	<100	ND	<100	ND
BIO-SB-1-28	26	28	1/14/2002	190	79	63	75,600	**308**	3,150	13	10J	0	<100	ND
BIO-SB-1-30	28	30	1/14/2002	191	95	72	117,000	**430**	2,950	11	<100	ND	<100	ND
BIO-SB-1-32	30	32	1/14/2002	194	170	135	75,100 S	156	10,800 S	22	39J	0	20J	0
BIO-SB-1-34	32	34	1/14/2002	191	81	71	7,390	26	9,940	35	<100	ND	<100	ND
BIO-SB-1-36	34	36	1/14/2002	193	119	104	205	1	6,670	17	45J	0	<100	ND
BIO-SB-1-38	36	38	1/14/2002	192	123	98	435	1	9,560	26	63J	0	<100	ND
BIO-SB-1-40	38	40	1/14/2002	192	126	96	<100	ND	6,070	17	55J	0	<100	ND
BIO-SB-1-42	40	42	1/14/2002	194	106	83	<100	ND	2,470	8	<100	ND	<100	ND
BIO-SB-1-MB (SS)	Lab Blank		1/14/2002	195	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-1-RINSATE	EQ		1/14/2002	NA	NA	NA	<1.0	ND	<1.0	ND	<1.0	ND	<1.0	ND
BIO-SB-2-8 (SS)	6	8	1/23/2002	190	103	101	140	0	<100	ND	<100	ND	<100	ND
BIO-SB-2-10	8	10	1/23/2002	191	114	99	587	2	268	1	<100	ND	<100	ND
BIO-SB-2-12	10	12	1/23/2002	192	118	106	1,500	4	653	2	<100	ND	<100	ND
BIO-SB-2-14	12	14	1/23/2002	190	141	119	5,710	13	3,040	7	<100	ND	19J	0
BIO-SB-2-14-DUP	12	14	1/23/2002	192	158	134	6,650	13	3,550	7	<100	ND	24J	0
BIO-SB-2-16	14	16	1/23/2002	191	141	131	23,100	44	5,690	11	24J	0	30J	0
BIO-SB-2-18	16	18	1/23/2002	190	210	176	47,200	74	5,120	8	30J	0	29J	0
BIO-SB-2-20	18	20	1/23/2002	190	164	146	44,100	78	4,680	8	19J	0	22J	0
BIO-SB-2-22	20	22	1/23/2002	191	163	135	45,700	91	6,830	14	24J	0	<100	ND
BIO-SB-2-24	22	24	1/23/2002	191	101	87	51,700	152	1,680	5	<100	ND	<100	ND
BIO-SB-2-26	24	26	1/23/2002	191	107	96	66,000	174	2,290	6	<100	ND	<100	ND
BIO-SB-2-28	26	28	1/23/2002	192	123	79	132,000	**480**	1,690	6	10J	0	<100	ND
BIO-SB-2-30	28	30	1/23/2002	191	174	137	196,000	**399**	2,470	5	<200	ND	<200	ND
BIO-SB-2-32	30	32	1/23/2002	191	156	112	176,000	**449**	5,270	13	<200	ND	<200	ND

Table C-2. Summary of CVOC Results in Soil for Pre-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft) Top Depth	Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (µg/L)	TCE Results in Dry Soil (mg/Kg)	*cis* -1,2-DCE Results in MeOH (µg/L)	*cis* -1,2-DCE Results in Dry Soil (mg/Kg)	*trans* -1,2-DCE Results in MeOH (µg/L)	*trans* -1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (µg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-2-34	32	34	1/23/2002	192	114	94	67,700	189	6,880	19	20J	0	<100	ND
BIO-SB-2-36	34	36	1/23/2002	191	201	168	58,500	96	20,200	33	58J	0	<100	ND
BIO-SB-2-38	36	38	1/23/2002	192	222	172	90,700	155	35,300	60	102	0	<100	ND
BIO-SB-2-40	38	40	1/23/2002	192	207	156	130,000	245	17,500	33	57J	0	<100	ND
BIO-SB-2-42	40	42	1/23/2002	192	145	100	83,800	241	26,900	77	81J	0	<100	ND
BIO-SB-2-44	42	44	1/23/2002	193	131	101	684	2	18,300	50	71J	0	<100	ND
BIO-SB-2-46	44	46	1/23/2002	192	110	85	805	3	5,310 S	17	17J	0	<100	ND
BIO-SB-2-MB (SS)	Lab Blank		1/23/2002	191	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-2-RINSATE	EQ		1/23/2002	NA	NA	NA	<1.0	ND	<1.0	ND	<1.0	ND	<1.0	ND
BIO-SB-3-8 (SS)	6	8	1/23/2002	187	83	85	127	0	11J	0	<100	ND	<100	ND
BIO-SB-3-10	8	10	1/23/2002	187	89	83	189	1	51J	0	<100	ND	<100	ND
BIO-SB-3-12	10	12	1/23/2002	188	127	116	480	1	153	0	<100	ND	<100	ND
BIO-SB-3-14	12	14	1/23/2002	189	144	125	4,080	8	1,930	4	<100	ND	<100	ND
BIO-SB-3-16	14	16	1/23/2002	192	111	96	8,830	24	3,090	8	<100	ND	<100	ND
BIO-SB-3-18	16	18	1/23/2002	191	113	100	3,240	8	1,630	4	<100	ND	<100	ND
BIO-SB-3-18-DUP	16	18	1/23/2002	195	107	94	12,100	33	3,060	8	<100	ND	23J	0
BIO-SB-3-20	18	20	1/23/2002	192	119	99	6,400	17	3,180	8	<100	ND	45J	0
BIO-SB-3-22	20	22	1/23/2002	194	94	74	14,100	51	3,460	12	12J	0	24J	0
BIO-SB-3-24	22	24	1/23/2002	191	110	95	29,700	80	2,700	7	<100	ND	<100	ND
BIO-SB-3-26	24	26	1/23/2002	191	106	95	31,100	83	2,870	8	<100	ND	<100	ND
BIO-SB-3-28	26	28	1/23/2002	192	143	120	63,100 S	140	4,600	10	18J	0	<100	ND
BIO-SB-3-30	28	30	1/23/2002	192	136	108	92,800	233	7,470	19	23J	0	<100	ND
BIO-SB-3-32	30	32	1/23/2002	192	107	86	32,300	99	13,600	42	40J	0	<100	ND
BIO-SB-3-34	32	34	1/23/2002	192	98	83	294	1	13,400	42	44J	0	<100	ND
BIO-SB-3-36	34	36	1/23/2002	192	153	131	185	0	5,730	12	37J	0	<100	ND
BIO-SB-3-38	36	38	1/23/2002	191	132	101	115	0	3,340	9	29J	0	<100	ND
BIO-SB-3-40	38	40	1/23/2002	192	121	90	170	1	24J	0	<100	ND	<100	ND
BIO-SB-3-42	40	42	1/23/2002	192	140	111	113	0	<100	ND	<100	ND	<100	ND
BIO-SB-3-44	42	44	1/23/2002	192	140	110	112	0	<100	ND	<100	ND	<100	ND
BIO-SB-3-46	44	46	1/23/2002	196	146	124	137	0	<100	ND	<100	ND	<100	ND
BIO-SB-3-MB (SS)	Lab Blank		1/23/2002	194	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-3-RINSATE	EQ		1/23/2002	NA	NA	NA	<1.0	ND	<1.0	ND	<1.0	ND	<1.0	ND
BIO-SB-4-8 (SS)	6	8	1/24/2002	195	100	107	113	0	<100	ND	<100	ND	<100	ND
BIO-SB-4-10	8	10	1/24/2002	194	125	87	291	1	84J	0	<100	ND	<100	ND
BIO-SB-4-12	10	12	1/24/2002	195	160	142	487	1	177	0	<100 S	ND	<100	ND

Table C-2. Summary of CVOC Results in Soil for Pre-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft) Top Depth	Sample Depth (ft) Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (µg/L)	TCE Results in Dry Soil (mg/Kg)	*cis*-1,2-DCE Results in MeOH (µg/L)	*cis*-1,2-DCE Results in Dry Soil (mg/Kg)	*trans*-1,2-DCE Results in MeOH (µg/L)	*trans*-1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (µg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-4-14	12	14	1/24/2002	196	128	111	4,280	10	2,520	6	<100	ND	39J	0
BIO-SB-4-16	14	16	1/24/2002	195	104	100	10,100	25	3,190	8	11J	0	25J	0
BIO-SB-4-18	16	18	1/24/2002	195	100	93	10,200	28	3,240	9	16J	0	<100	ND
BIO-SB-4-20	18	20	1/24/2002	196	170	144	18,000	34	4,530	9	26J	0	<100	ND
BIO-SB-4-22	20	22	1/24/2002	195	103	85	38,600	120	3,960	12	<100	ND	<100	ND
BIO-SB-4-24	22	24	1/24/2002	195	119	101	37,600	99	2,580	7	<100	ND	<100	ND
BIO-SB-4-26	24	26	1/24/2002	195	94	78	51,300	173	1,860	6	<100	ND	<100	ND
BIO-SB-4-28	26	28	1/24/2002	195	109	91	102,000	**297**	3,450	10	<100	ND	<100	ND
BIO-SB-4-30	28	30	1/24/2002	193	143	116	173,000	**405**	3,460	8	<100	ND	15J	0
BIO-SB-4-32	30	32	1/24/2002	195	94	77	52,200	179	10,300	35	<100	ND	<100	ND
BIO-SB-4-34	32	34	1/24/2002	194	143	118	4,570	10	25,500	58	86J	0	<100	ND
BIO-SB-4-36	34	36	1/24/2002	194	93	78	<100	ND	9,230	31	<100	ND	<100	ND
BIO-SB-4-38	36	38	1/24/2002	194	121	98	<100	ND	8,470	23	39J	0	<100	ND
BIO-SB-4-40	38	40	1/24/2002	195	144	109	<100	ND	6,960	18	30J	0	<100	ND
BIO-SB-4-42	40	42	1/24/2002	189	98	75	<100	ND	1,100	4	<100	ND	<100	ND
BIO-SB-4-42-DUP	40	42	1/24/2002	189	103	81	<100	ND	1,110	4	<100	ND	<100	ND
BIO-SB-4-44	42	44	1/24/2002	194	133	100	<100	ND	170	0	<100	ND	<100	ND
BIO-SB-4-46	44	46	1/24/2002	194	140	121	<100	ND	171	0	<100	ND	<100	ND
BIO-SB-4-MB (SS)	Lab Blank		1/24/2002	194	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-4-RINSATE	EQ		1/24/2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-5-8 (SS)	6	8	2/4/2002	195	75	77	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-5-10	8	10	2/4/2002	195	108	97	170	0	<100	ND	<100	ND	<100	ND
BIO-SB-5-12	10	12	2/4/2002	194	103	94	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-5-14	12	14	2/4/2002	194	106	93	259	1	158	0	<100	ND	<100	ND
BIO-SB-5-16	14	16	2/4/2002	196	117	101	5,090	13	1,820	5	<100	ND	<100	ND
BIO-SB-5-18	16	18	2/4/2002	194	118	103	15,900	40	2,770	7	<100	ND	<100	ND
BIO-SB-5-20	18	20	2/4/2002	195	107	97	211,000	**559**	3,090	8	<100	ND	<100	ND
BIO-SB-5-22	20	22	2/4/2002	188	126	107	80,700	194	2,140	5	<100	ND	<100	ND
BIO-SB-5-24	22	24	2/4/2002	193	134	116	425,000	**961**	2,590	6	<100	ND	<100	ND
BIO-SB-5-26	24	26	2/4/2002	195	132	111	81,800	197	1,320	3	<100	ND	<100	ND
BIO-SB-5-28	26	28	2/4/2002	195	101	83	93,900	**300**	855	3	<100	ND	<100	ND
BIO-SB-5-30	28	30	2/4/2002	193	134	104	175,000	**462**	1,020	3	<100	ND	16J	0
BIO-SB-5-32	30	32	2/4/2002	194	137	113	1,690,000	**4,032**	3,140	7	<1,000	ND	<1,000	ND
BIO-SB-5-34	32	34	2/4/2002	195	125	104	151,000	**389**	1,450	4	<100	ND	<100	ND
BIO-SB-5-36	34	36	2/4/2002	196	173	142	113,000	222	5,400	11	<100	ND	<100	ND
BIO-SB-5-38	36	38	2/4/2002	194	107	89	104,000	**308**	8,140	24	13J	0	<100	ND
BIO-SB-5-38-DUP	36	38	2/4/2002	193	82	73	82,600	**287**	4,940	17	<100	ND	<100	ND
BIO-SB-5-40	38	40	2/4/2002	193	248	183	296,000	**500**	12,700	21	28J	0	<100	ND

Table C-2. Summary of CVOC Results in Soil for Pre-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft) Top Depth	Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (µg/L)	TCE Results in Dry Soil (mg/Kg)	*cis*-1,2-DCE Results in MeOH (µg/L)	*cis*-1,2-DCE Results in Dry Soil (mg/Kg)	*trans*-1,2-DCE Results in MeOH (µg/L)	*trans*-1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (µg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-5-42	40	42	2/4/2002	195	179	138	177,000	**369**	5,960	12	<100	ND	<100	ND
BIO-SB-5-MB (SS)	Lab Blank		2/4/2002	193	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-5-RINSATE	EQ		2/4/2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-6-8 (SS)	6	8	2/5/2002	194	68	69	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-6-10	8	10	2/5/2002	190	88	78	666	2	625	2	<100	ND	<100	ND
BIO-SB-6-12	10	12	2/5/2002	193	142	137	1,200	2	1,080	2	<100	ND	<100	ND
BIO-SB-6-14	12	14	2/5/2002	194	138	122	447	1	478	1	<100	ND	<100	ND
BIO-SB-6-16	14	16	2/5/2002	192	97	82	1,700	5	907	3	<100	ND	<100	ND
BIO-SB-6-18	16	18	2/5/2002	193	115	100	4,370	11	1,410	4	<100	ND	<100	ND
BIO-SB-6-20	18	20	2/5/2002	193	135	116	42,100	96	4,700	11	12J	0	<100	ND
BIO-SB-6-22	20	22	2/5/2002	193	177	151	58,800	105	5,800	10	18J	0	<100	ND
BIO-SB-6-24	22	24	2/5/2002	191	148	133	84,200	163	1,690	3	<100	ND	<100	ND
BIO-SB-6-26	24	26	2/5/2002	194	129	109	95,000	231	808	2	<100	ND	<100	ND
BIO-SB-6-28	26	28	2/5/2002	195	109	88	138,000	**420**	719	2	<100	ND	<100	ND
BIO-SB-6-28-DUP	26	28	2/5/2002	193	78	66	93,000	**361**	472	2	<100	ND	<100	ND
BIO-SB-6-30	28	30	2/5/2002	195	130	98	141,000	**401**	721	2	<100	ND	<100	ND
BIO-SB-6-32	30	32	2/5/2002	195	112	91	698,000	**2,054**	1,120	3	<100	ND	<100	ND
BIO-SB-6-34	32	34	2/5/2002	194	108	101	99,900	**250**	471	1	<100	ND	<100	ND
BIO-SB-6-36	34	36	2/5/2002	193	142	122	962,000	**2,084**	640J	0	<1,000	ND	<1,000	ND
BIO-SB-6-38	36	38	2/5/2002	192	140	113	1,260,000	**3,011**	910J	0	<1,000	ND	<1,000	ND
BIO-SB-6-40	38	40	2/5/2002	193	186	136	294,000	**636**	457	1	<100	ND	<100	ND
BIO-SB-6-42	40	42	2/5/2002	194	155	129	183,000	**385**	288	1	<100	ND	<100	ND
BIO-SB-6-MB (SS)	Lab Blank		2/5/2002	191	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-6-RINSATE	EQ		2/5/2002	NA	NA	NA	<1.0	ND	<1.0	ND	<1.0	ND	<1.0	ND
BIO-SB-7-8 (SS)	6	8	2/6/2002	196	71	72	174	1	35J	0	<100	ND	<100	ND
BIO-SB-7-10	8	10	2/6/2002	194	132	117	736	2	713	2	<100	ND	<100	ND
BIO-SB-7-12	10	12	2/6/2002	194	136	120	1,290	3	1,180	3	<100	ND	<100	ND
BIO-SB-7-14	12	14	2/6/2002	195	132	114	3,090	7	2,620	6	<100	ND	<100	ND
BIO-SB-7-16	14	16	2/6/2002	195	122	109	2,630	6	2,700	6	<100	ND	<100	ND
BIO-SB-7-18	16	18	2/6/2002	192	119	104	2,900	7	1,940	5	<100	ND	<100	ND
BIO-SB-7-20	18	20	2/6/2002	192	177	132	8,670	19	4,550	10	19J	0	44J	0
BIO-SB-7-22	20	22	2/6/2002	193	116	102	5,820	15	3,400	9	12J	0	34J	0
BIO-SB-7-22-DUP	20	22	2/6/2002	195	95	86	4,830	14	2,440	7	<100	ND	22J	0
BIO-SB-7-24	22	24	2/6/2002	192	118	100	61,300	160	1,800	5	<100	ND	<100	ND
BIO-SB-7-26	24	26	2/6/2002	191	124	102	3,220,000	**8,327**	4,460	12	64J	0	<100	ND

Table C-2. Summary of CVOC Results in Soil for Pre-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft)		Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE		*cis* -1,2-DCE		*trans* -1,2-DCE		Vinyl Chloride	
	Top Depth	Bottom Depth					Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)	Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)	Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)	Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)
BIO-SB-7-28	26	28	2/6/2002	193	139	113	428,000	**1,024**	1,190	3	11J	0	<100	ND
BIO-SB-7-30	28	30	2/6/2002	194	122	101	160,000	**422**	929	2	<100	ND	<100	ND
BIO-SB-7-32	30	32	2/6/2002	192	124	103	129,000	**331**	672	2	<100	ND	<100	ND
BIO-SB-7-34	32	34	2/6/2002	193	137	117	111,000	**251**	618	1	<100	ND	<100	ND
BIO-SB-7-36	34	36	2/6/2002	192	241	196	425,000	**625**	7,620	11	<500	ND	<500	ND
BIO-SB-7-38	36	38	2/6/2002	194	201	171	2,310,000	**3,723**	6,380	10	<1,000	ND	<1,000	ND
BIO-SB-7-40	38	40	2/6/2002	194	159	113	147,000	**379**	19,400	50	42J	0	<100	ND
BIO-SB-7-42	40	42	2/6/2002	195	136	105	33,100	88	17,000	45	55J	0	<100	ND
BIO-SB-7-MB (SS)	Lab Blank		2/6/2002	194	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-7-RINSATE	EQ		2/6/2002	NA	NA	NA	<1.0	ND	<1.0	ND	<1.0	ND	<1.0	ND

NA: Not available.
ND: Not detected.
DUP: Duplicate sample.
EQ: Equipment rinsate.
MB: Method blank.
SS: Surrogate spiked.
J: Result was estimated but below the reporting limit.
S: Spike Recovery outside accepted recovery limits due to the high concentration present in the sample.
R: RPD for MS/MSD outside accepted receovery limits.
Boldface in shading denotes that TCE level is exceeding or near the saturation level (approximately 300 mg/kg, see Section 2.3).

Table C-3. Summary of CVOC Results in Soil for Post-demonstration Monitoring in Bioaugmentation Plot

Sample ID	Sample Depth (ft) Top Depth	Sample Depth (ft) Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (µg/L)	TCE Results in Dry Soil (mg/Kg)	cis -1,2-DCE Results in MeOH (µg/L)	cis -1,2-DCE Results in Dry Soil (mg/Kg)	trans -1,2-DCE Results in MeOH (µg/L)	trans -1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (µg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-202-8	6	8	6/17/2003	189	231.5	212	344	0	503	1	<100	ND	103	0
BIO-SB-202-10	8	10	6/17/2003	191	174.5	153.5	318	1	686	1	<100	ND	526	1
BIO-SB-202-12	10	12	6/17/2003	191.5	224	186	117	0	283	0	29	0	677	1
BIO-SB-202-14	12	14	6/17/2003	193.5	245.5	205	142	0	371	1	33 J	0	418	1
BIO-SB-202-16	14	16	6/17/2003	191.5	199	165	109	0	25 J	0	24 J	0	<100	ND
BIO-SB-202-18	16	18	6/17/2003	192.5	201.5	171	115	0	32 J	0	20 J	0	27 J	0
BIO-SB-202-20	18	20	6/17/2003	191	198.5	170.5	<100	ND	18 J	0	<100	ND	<100	ND
BIO-SB-202-20-DUP	18	20	6/17/2003	196	190	163.5	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-202-22	20	22	6/17/2003	193	245.5	203	120	0	26 J	0	33 J	0	2,350	3
BIO-SB-202-24	22	24	6/17/2003	191.5	208	172	<100	ND	1,380	2	30 J	0	4,280	7
BIO-SB-202-26	24	26	6/17/2003	191.5	172	141.5	<100	ND	3,900	8	27 J	0	5,040	10
BIO-SB-202-28	26	28	6/17/2003	192	287	231	<100	ND	7,180	9	55 J	0	8,360	11
BIO-SB-202-30	28	30	6/17/2003	189.5	192	149	168,000	**319**	2,450	5	<100	ND	50 J	0
BIO-SB-202-32	30	32	6/17/2003	191.5	301.5	233.5	282,000	**375**	6,310	8	<100	ND	40 J	0
BIO-SB-202-34	32	34	6/17/2003	189	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-202-36	34	36	6/17/2003	188.5	276.5	225	221,000	285	9,630	12	24 J	0	21 J	0
BIO-SB-202-38	36	38	6/17/2003	194	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-202-40	38	40	6/17/2003	189.5	229	183	159,000	248	12,700	20	43 J	0	<100	ND
BIO-SB-202-42 (SS)	40	42	6/17/2003	192.5	256	198	967,000	**1,473**	35,500	54	110	0	<100	ND
BIO-SB-202-MeOH	Lab Blank		6/17/2003	192.5	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-202-RINSATE	EQ		6/17/2003	NA	NA	NA	<1.0	NA	<1.0	ND	<1.0	ND	<1.0	ND
BIO-SB-205-8	6	8	6/18/2003	190.5	228.5	222	328	0	186	0	<100	ND	<100	ND
BIO-SB-205-10	8	10	6/18/2003	191.5	206	184	135	0	214	0	<100	ND	239	0
BIO-SB-205-12	10	12	6/18/2003	193	229.5	193	109	0	152	0	26 J	0	251	0
BIO-SB-205-14	12	14	6/18/2003	194	172	145	<100	ND	12 J	0	23 J	0	296	1
BIO-SB-205-16	14	16	6/18/2003	193	222.5	182	<100	ND	31 J	0	26 J	0	218	0
BIO-SB-205-16-DUP	14	16	6/18/2003	193	191.5	141	<100	ND	<100	ND	19 J	0	112	0
BIO-SB-205-18	16	18	6/18/2003	192.5	191	157.5	<100	ND	60 J	0	27 J	0	1,180	2
BIO-SB-205-20	18	20	6/18/2003	193.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-205-22	20	22	6/18/2003	192.5	304.5	249.5	<100	ND	538	1	51 J	0	3,620	4
BIO-SB-205-24	22	24	6/18/2003	192	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-205-26	24	26	6/18/2003	196.5	217.5	174.5	<100	ND	433	1	42 J	0	3,170	5
BIO-SB-205-28	26	28	6/18/2003	192.5	134.5	103	1,680	4	4,280	11	26 J	0	4,260	11
BIO-SB-205-30	28	30	6/18/2003	193.5	206	159	921,000	**1,691**	7,350	13	<100	ND	350 J	1
BIO-SB-205-32	30	32	6/18/2003	192.5	165	125.5	878,000	**1,981**	6,350	14	<500	ND	290 J	1

Table C-3. Summary of CVOC Results in Soil for Post-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft)		Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE		*cis*-1,2-DCE		*trans*-1,2-DCE		Vinyl Chloride	
	Top Depth	Bottom Depth					Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)	Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)	Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)	Results in MeOH (µg/L)	Results in Dry Soil (mg/Kg)
BIO-SB-205-34	32	34	6/18/2003	189	230	183	257,000	**402**	2,100	3	<100	ND	31 J	0
BIO-SB-205-36	34	36	6/18/2003	193.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-205-38	36	38	6/18/2003	194	318	253	896,000	**1,100**	14,600	18	<500	ND	<500	ND
BIO-SB-205-40	38	40	6/18/2003	193	251.5	198.5	1,370,000	**2,052**	18,800	28	<1,000	ND	<1,000	ND
BIO-SB-205-42 (SS)	40	42	6/18/2003	194	170	127.5	900,000	**2,033**	10,100	23	<500	ND	<500	ND
BIO-SB-205-45	43	45	6/18/2003	189.5	184	143.5	113,000	221	18,100	35	58 J	0	<100	ND
BIO-SB-205-MeOH	Lab Blank		6/18/2003	193.5	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-205-RINSATE	EQ		6/18/2003	NA	NA	NA	3	NA	<1	ND	<1	ND	<1	ND
BIO-SB-206-8 (SS)	6	8	6/19/2003	191	170	157	335	1	152	0	<100	ND	<100	ND
BIO-SB-206-10	8	10	6/19/2003	193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-206-12	10	12	6/19/2003	191	212	178	114	0	148	0	<100	ND	395	1
BIO-SB-206-14	12	14	6/19/2003	191.5	179	149.5	<100	ND	55 J	0	22 J	0	132	0
BIO-SB-206-16	14	16	6/19/2003	192.5	127.5	108	<100	ND	<100	ND	<100	ND	98 J	0
BIO-SB-206-18	16	18	6/19/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-206-20	18	20	6/19/2003	193.5	233	194	<100	ND	<100	ND	31 J	0	1,370	2
BIO-SB-206-22	20	22	6/19/2003	193.5	189	152.5	<100	ND	73 J	0	32 J	0	1,120	2
BIO-SB-206-22-DUP	20	22	6/19/2003	193	141	115	<100	ND	166	0	24 J	0	854	2
BIO-SB-206-24	22	24	6/19/2003	193	NA	NA	NA	NA	NA	NA	Na	NA	NA	NA
BIO-SB-206-26	24	26	6/19/2003	193.5	154.5	132	917	2	<100	ND	<100	ND	260	1
BIO-SB-206-28	26	28	6/19/2003	193	178.5	144.5	<100	ND	24 J	0	44 J	0	2,960	6
BIO-SB-206-30	28	30	6/19/2003	193.5	181	137.5	11,700	25	14,600	31	76 J	0	5,060	11
BIO-SB-206-32	30	32	6/19/2003	192.5	207.5	158.5	1,370,000	**2,530**	5,090	9	<100	ND	98 J	0
BIO-SB-206-34	32	34	6/19/2003	191.5	165.5	129.5	714,000	**1,535**	3,930	8	43 J	0	84 J	0
BIO-SB-206-36	34	36	6/19/2003	194	224	178	723,000	**1,184**	2,720	4	25 J	0	47 J	0
BIO-SB-206-38	36	38	6/19/2003	194	220	163	295,000	**548**	646	1	<100	ND	<100	ND
BIO-SB-206-40 (SS)	38	40	6/19/2003	193.5	242.5	183	3,740,000	**6,222**	2,600	4	<100	ND	30 J	0
BIO-SB-206-MeOH	Lab Blank		6/19/2003	193	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-207-8	6	8	6/20/2003	192.5	170	153	397	1	253	0	<100	ND	407	1
BIO-SB-207-10	8	10	6/20/2003	193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-207-12	10	12	6/20/2003	193.5	184.5	156.5	143	0	177	0	<100	ND	1,310	2
BIO-SB-207-14	12	14	6/20/2003	192.5	200.5	170.5	<100	ND	42 J	0	29 J	0	1,340	2
BIO-SB-207-16	14	16	6/20/2003	192	245.5	203	<100	ND	<100	ND	22 J	0	<100	ND
BIO-SB-207-18	16	18	6/20/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-207-20	18	20	6/20/2003	192.5	197	165	1,860	3	4,100	7	27 J	0	1,420	2
BIO-SB-207-22	20	22	6/20/2003	191	174	141.5	3,920	8	18,200	35	76 J	0	4,880	9

Table C-3. Summary of CVOC Results in Soil for Post-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft) Top Depth	Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (µg/L)	TCE Results in Dry Soil (mg/Kg)	*cis*-1,2-DCE Results in MeOH (µg/L)	*cis*-1,2-DCE Results in Dry Soil (mg/Kg)	*trans*-1,2-DCE Results in MeOH (µg/L)	*trans*-1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (µg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-207-24	22	24	6/20/2003	193	167	135.5	839	2	10,100	21	48 J	0	4,650	9
BIO-SB-207-26	24	26	6/20/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-207-28	26	28	6/20/2003	193.5	223.5	182	75,000	118	29,100	46	72 J	0	4,120	6
BIO-SB-207-28-DUP	26	28	6/20/2003	192	134	107	55,800	141	15,700	40	42 J	0	2,250	6
BIO-SB-207-30	28	30	6/20/2003	191	183	139.5	93,200	191	1,650	3	<100	ND	29 J	0
BIO-SB-207-32	30	32	6/20/2003	192.5	211	161	196,000	**358**	1,700	3	<100	ND	40 J	0
BIO-SB-207-34	32	34	6/20/2003	192	206.5	162.5	204,000	**360**	1,500	3	<100	ND	29 J	0
BIO-SB-207-36	34	36	6/20/2003	191	280.5	223	304,000	**408**	1,740	2	<200	ND	<200	ND
BIO-SB-207-38	36	38	6/20/2003	192	165	121.5	206,000	**486**	6,150	15	<200	ND	<200	ND
BIO-SB-207-40 (SS)	38	40	6/20/2003	192	214	162.5	159,000	288	21,300	39	<200	ND	<200	ND
BIO-SB-207-MeOH	Lab Blank		6/20/2003	192.5	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-207-RINSATE	EQ		6/20/2003	NA	NA	NA	4.53	NA	<1.0	ND	<1.0	ND	<1.0	ND
BIO-SB-210-15	14	15	6/18/2003	193.5	193	164.5	849	1	<100	ND	22 J	0	<100	ND
BIO-SB-210-16	15	16	6/18/2003	193	207.5	174.5	3,600	6	419	1	27 J	0	920	1
BIO-SB-210-17	16	17	6/18/2003	193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-210-18	17	18	6/18/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-210-19	18	19	6/18/2003	193.5	175	145.5	<100	ND	44 J	0	26 J	0	4,750	9
BIO-SB-210-20	19	20	6/18/2003	192.5	226.5	192.5	540	1	40 J	0	27 J	0	3,380	5
BIO-SB-210-20-DUP	19	20	6/18/2003	193.5	167.5	143.5	165	0	<100	ND	<100	ND	1,690	3
BIO-SB-210-21	20	21	6/18/2003	193.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-210-22	21	22	6/18/2003	193.5	161	138	365	1	381	1	<100	ND	2,320	5
BIO-SB-210-23	22	23	6/18/2003	193	187.5	149.5	290	1	1,620	3	<100	ND	3,140	6
BIO-SB-210-24	23	24	6/18/2003	193	201.5	165	806	1	173	0	34 J	0	865	1
BIO-SB-210-25	24	25	6/18/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-210-26	25	26	6/18/2003	193	193	159	<100	ND	<100	ND	<100	ND	37 J	0
BIO-SB-210-27	26	27	6/18/2003	193	141	112.5	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-210-28	27	28	6/18/2003	191.5	190	149	300	1	5,820	11	54 J	0	4,370	8
BIO-SB-210-29	28	29	6/18/2003	194	181.5	140.5	7,000,000	**14,277**	4,090	8	47 J	0	38 J	0
BIO-SB-210-30 (SS)	29	30	6/18/2003	193.5	180.5	135	140,000	**301**	12,800	28	52 J	0	998	2
BIO-SB-210-MeOH	Lab Blank		6/18/2003	193.5	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND
BIO-SB-211-15	14	15	6/19/2003	194	177	149.5	1,100	2	17 J	0	17 J	0	457	1
BIO-SB-211-16	15	16	6/19/2003	194	179.5	154	591	1	<100	ND	<100	ND	<100	ND
BIO-SB-211-17	16	17	6/19/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-211-18	17	18	6/19/2003	192.5	177	132	<100	ND	<100	ND	<100	ND	148	0
BIO-SB-211-19	18	19	6/19/2003	193.5	157.5	147.5	<100	ND	<100	ND	38 J	0	37 J	0

Table C-3. Summary of CVOC Results in Soil for Post-demonstration Monitoring in Bioaugmentation Plot (Continued)

Sample ID	Sample Depth (ft) Top Depth	Sample Depth (ft) Bottom Depth	Sample Date	MeOH (g)	Wet Soil Weight (g)	Dry Soil Weight (g)	TCE Results in MeOH (μg/L)	TCE Results in Dry Soil (mg/Kg)	*cis* -1,2-DCE Results in MeOH (μg/L)	*cis* -1,2-DCE Results in Dry Soil (mg/Kg)	*trans* -1,2-DCE Results in MeOH (μg/L)	*trans* -1,2-DCE Results in Dry Soil (mg/Kg)	Vinyl Chloride Results in MeOH (μg/L)	Vinyl Chloride Results in Dry Soil (mg/Kg)
BIO-SB-211-20	19	20	6/19/2003	191	193.5	159	145	0	<100	ND	24 J	0	2,410	4
BIO-SB-211-21	20	21	6/19/2003	193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-211-22	21	22	6/19/2003	191.5	197.5	165.5	385	1	<100	ND	34 J	0	257	0
BIO-SB-211-23	22	23	6/19/2003	193	142	115.5	<100	ND	<100	ND	25 J	0	21 J	0
BIO-SB-211-24	23	24	6/19/2003	193	147	118.5	384	1	<100	ND	25 J	0	750	2
BIO-SB-211-24-DUP	23	24	6/19/2003	192.5	158.5	128.5	224	0	<100	ND	<100	ND	260	1
BIO-SB-211-25	24	25	6/19/2003	192.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-211-26	25	26	6/19/2003	191.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIO-SB-211-27	26	27	6/19/2003	193.5	155	124.5	209	0	<100	ND	26 J	0	436	1
BIO-SB-211-28	27	28	6/19/2003	195.5	203.5	161.5	169	0	3,570	6	65 J	0	8,330	15
BIO-SB-211-29	28	29	6/19/2003	192	182.5	140	105	0	6,980	14	70 J	0	10,700	22
BIO-SB-211-30 (SS)	29	30	6/19/2003	190.5	181.5	134.5	4,760	10	13,200	28	73 J	0	5,960	13
BIO-SB-211-MeOH	Lab Blank		6/19/2003	193	NA	NA	<100	ND	<100	ND	<100	ND	<100	ND

NA: Not available.
ND: Not detected.
DUP: Duplicate sample.
EQ: Equipment rinsate.
MB: Method blank.
SS: Surrogate spiked.
J: Result was estimated but below the reporting limit.
Boldface in shading denotes that TCE level is exceeding or near the saturation level (approximately 300 mg/kg, see Section 2.3).

Table C-4. Long-Term Monitoring Results in Treatment Plot

	CVOC (µg/L)				Dissolved Gases (mg/L)		
Well ID	**TCE**	***cis*-1,2-DCE**	***trans*-1,2-DCE**	**Vinyl Chloride**	**Methane**	**Ethane**	**Ethene**
MW-6	<10	35.6	104	875	4.83	0.00377	7.07
PA-26	<10	62.4	143	161	4.36	<0.002	4.38

	Inorganics (mg/L)						
Well ID	**Calcium**	**Iron**	**Magnesium**	**Manganese**	**Potassium**	**Sodium**	**Alkalinity**
MW-6	731	18.8	46.3	0.255	50.9	72.2	1,090
PA-26	1,050	22.8	55.3	1.44	62.4	78	1,550

	Anions (mg/L)					Others (mg/L)
Well ID	**Bromide**	**Chloride**	**Nitrate (NO_3)**	**Phosphate**	**Sulfate**	**TDS**
MW-6	0.67J	406	2.3	<0.5	<3	3,730
PA-26	<1	389	3.42	<0.5	<3	4,980

Groundwater monitoring was conducted on January 22, 2004 (approximately one year after KB-1™ culture application).

Table C-5. Monitoring Results of CVOCs and Dechlorination Products in Groundwater from PA-26

PA-26	Pre-demo (µg/L)	Post-demo (µg/L)	Long-Term (µg/L)	Pre-demo (mmole/L)	Post-demo (mmole/L)	Long-Term (mmole/L)
TCE	1,220,000	239	<10	9.31	0.00	<0.08
cis -1,2-DCE	31,600	780	62.4	0.33	0.01	0.00
trans- 1,2-DCE	<1,000	436	143	<0.02	0.00	0.00
VC	<1,000	8,040	161	<0.02	0.13	0.00
ethene	573	22,900	4,380	0.02	0.82	0.16
Chloride	246,000	311,000	389,000	6.94	8.77	10.97

Pre-demo: March 2002.

Post-demo: June 2003.

Long-Term: January 2004.

Assuming a complete dechlorination occurred in the treatment plot, an increase in chloride was 65 mg/L from the post-demo monitoring.

A complete dechlorination of 1.23 mg/L of TCE will result in 1 mg/L of chloride production on the basis of stoichometric balance.

The increase in chloride concentration of 65 mg/L observed in the post-demonstration monitoring suggests that approximately 80 mg/L of TCE could have been dechlorinated. A continuous dechlorination process appeared to have taken place from the long-term monitoring (approximately 1 year after the addition of KB-1 cultures). An additional 78 mg/L of chloride was observed from the monitoring. As a result of the dechlorination, the additional dechlorination of 96 mg/L of TCE could have been dechlorinated. The total TCE reduction may be 176 mg/L since the demonstration was performed at the site.

Table C-6. Results of Extracted Groundwater for Chloroethene and Ethene Concentraions at the Inflent Sample Port (SP-4) of Carbon Tanks

Flow rate (gpm)	Sampling Date	*Groundwater Mass Discharge[1] (mmole/day)*					Total Ethenes Mass Discharge (kg/day)	TCE Mass Discharge (kg/day)	Operating days (days)	Cumulative Total Ethenes Mass Removed (Kg)	Cumulative TCE Mass Removed in Carbon Tanks (Kg)
		TCE	*cis*-1,2-DCE	VC	Ethene	Total Ethenes[2]					
NA	5/23/02	NA	NA	NA	NA	NA	NA	NA	0	NA	NA
1.5	5/30/02	5,971	1,769	74	NM	7,814	1.02	0.78	7	0	3
1.5	6/17/02	746	118	1	2.9	868	0.11	0.10	18	10	11
1.5	6/27/02	16,172	1,937	33	58	18,199	2.38	2.12	10	23	22
1.5	7/3/02	16,794	1,684	27	58	18,563	2.43	2.20	6	37	35
1.5	7/9/02	15,550	1,516	26	58	17,149	2.25	2.04	6	51	47
1.5	7/11/02	11,818	1,179	26	58	13,081	1.71	1.55	2	55	51
1.5	7/15/02	13,062	1,263	26	58	14,409	1.89	1.71	4	62	58
1.4	7/18/02	12,191	1,022	24	54	13,291	1.74	1.60	3	68	62
1.5	7/23/02	13,062	1,011	26	58	14,156	1.85	1.71	5	77	71
1.5	7/25/02	12,440	1,011	26	58	13,534	1.77	1.63	2	80	74
1.5	7/29/02	11,196	766	26	58	12,046	1.58	1.47	4	87	80
1.5	8/1/02	12,440	741	26	58	13,265	1.74	1.63	3	92	85
1.4	8/7/02	9,869	566	24	54	10,513	1.38	1.29	6	101	94
1.5	8/14/02	9,952	531	26	58	10,566	1.38	1.30	7	111	103
1.4	8/19/02	9,288	464	24	54	9,830	1.29	1.22	5	118	109
1.5	8/22/02	9,952	472	26	58	10,507	1.38	1.30	3	122	113
1.5	8/28/02	10,574	463	26	58	11,121	1.46	1.39	6	130	121
1.5	9/4/02	9,952	438	26	58	10,473	1.37	1.30	7	140	130
1.5	9/12/02	9,330	421	26	58	9,835	1.29	1.22	8	151	140
1.4	10/2/02	9,288	377	24	54	9,744	1.28	1.22	20	176	NA
1.5	10/17/02	9,952	430	26	58	10,465	1.37	1.30	15	196	NA
1.4	11/5/02	8,127	495	24	54	8,701	1.14	1.06	19	220	NA
1.2	11/21/02	7,961	613	52	115	8,742	1.15	1.04	16	238	NA
1.5	12/11/02	8,086	2,274	26	58	10,444	1.37	1.06	20	264	NA
1.5	12/18/02	8,086	3,116	99	58	11,359	1.49	1.06	7	274	NA
1.5	12/23/02	6,220	3,453	143	58	9,874	1.29	0.81	5	281	NA
0.5	1/7/03	2,281	1,741	200	19	4,240	0.56	0.30	15	294	NA
0.8	1/22/03	3,981	3,234	508	34	7,756	1.02	0.52	15	306	NA
1.0	2/7/03	16.2	4,604	2,782	500	7,902	1.04	0.00	16	323	NA
0.60	3/4/03	2,115	1,785	782	150	4,833	0.63	0.28	25	343	NA
0.40	3/19/03	1,443	1,235	591	138	3,408	0.45	0.19	15	352	NA
0.50	4/3/03	1,673	1,906	795	49	4,424	0.58	0.22	15	359	NA
0.50	4/20/03	1,650	1,637	3,333	356	6,976	0.91	0.22	17	372	NA
0.50	5/30/03	1,298	1,305	995	144	3,743	0.49	0.17	40	400	NA
0.47	7/31/03	1,111	1,108	899	2,351	5,469	0.72	0.15	62	437	NA
0.50	9/3/03	560	1,404	739	2,404	5,107	0.67	0.07	34	461	NA
0.50	10/14/03	155.5	2,442	782	2,308	5,688	0.75	0.02	41	490	NA

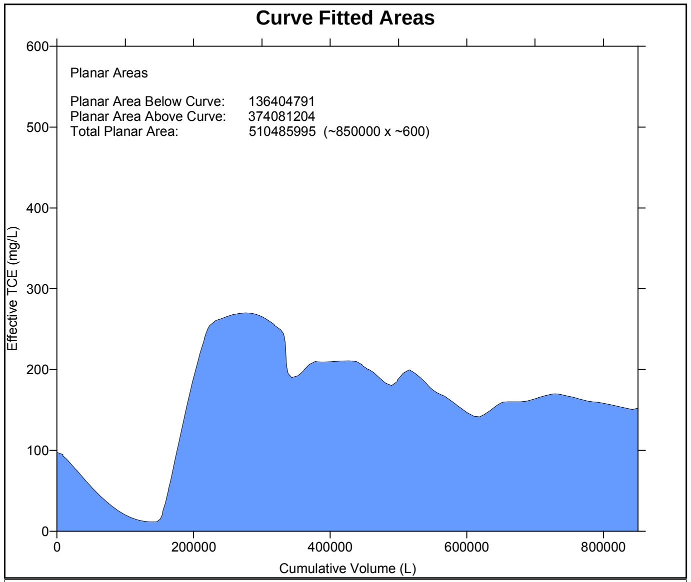
NA: Not available.
NM: Not measured.
1. Mass discharge determined using an average daily flow rate .
2. Includes TCE, *cis*-1,2-DCE, VC and ethene

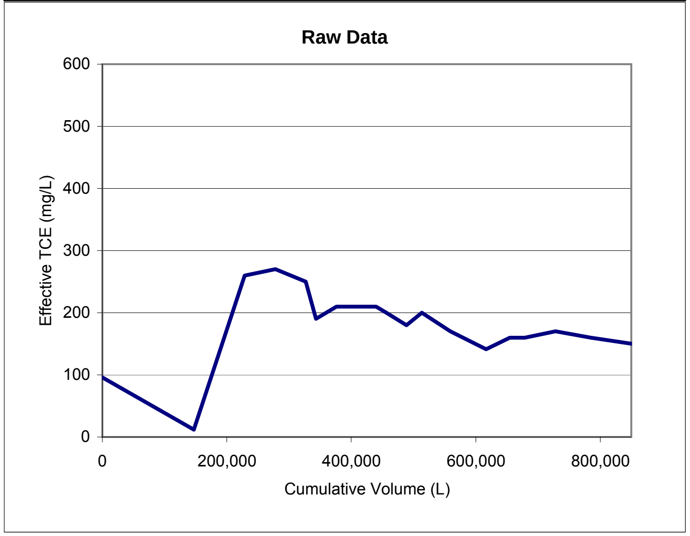
The extracted groundwater was collected from the sample port (the influent combined manifold [SP-4] of the carbon canisters). The recirculated groundwater was flowed into the carbon canisters until September 12, 2003. Thus, the TCE mass removed in the carbon canisters was estimated using a set of data until the date.

Table C-6. Results of Extracted Groundwater for Chloroethene and Ethene Concentraions at the Inflent Sample Port (SP-4) of Carbon Tanks (Continued)

Volume (L)	Cumulative Vol (L)	Influent TCE (mg/L)	Effluent TCE (mg/L)	Effective TCE (mg/L)	Mass (kg)
0	0	96	0.016	96	0
147,161	147,161	12	<0.10	12	1.75
81,756	228,917	260	<0.01	260	21.3
49,054	277,971	270	0.01	270	13.2
49,054	327,025	250	0.01	250	12.3
16,351	343,376	190	0.01	190	3.1
32,702	376,079	210	0.01	210	6.9
22,892	398,970	210	0.01	210	4.8
40,878	439,849	210	0.05	210	8.6
16,351	456,200	200	0.01	200	3.3
32,702	488,902	180	0.01	180	5.9
24,527	513,429	200	0.01	200	4.9
45,783	559,213	170	0.01	170	7.8
57,229	616,442	160	19	141	8.1
38,153	654,595	160	0.01	160	6.1
24,527	679,122	160	0.01	160	3.9
49,054	728,176	170	0.01	170	8.3
57,229	785,405	160	0.01	160	9.2
65,405	850,810	150	0.01	150	9.8

Calculated Mass	139.1
Fitted Mass	136.4
Difference	-2.0%





Pore Volume Calculation

Dimension 20 ft wide Volume: 8,000 ft^3

20 ft deep

20 ft thickness for the sat. zone (from 6 to 26 ft bgs in the Upper Sand Unit)

Porosity 0.33

Pore Space 2,640 ft^3 1 gal = 0.1337 ft^3

in the plot. 19,746 gals

Total extracted groundwater into the carbon cannisters: 239,904 gals. 12 PV's

Approximately, 12 PV's of groundwater flowed into the carbon cannisters until September 12, 2004.

Appendix D

Inorganic and Other Aquifer Parameters

Table D-1. Summary of Field Parameters in Groundwater

Well ID	Temperature (°C)				DO (mg/L)				pH			
	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well												
PA-26	27.2	28.7	27.9	27.9	0.89	0.26	0.17	0.30	6.55	7.16	7.96	6.5
BIO Perimeter Wells												
PA-27S	30.6	29.5	28.8	28.6	0.73	1.19	0.23	0.21	6.64	7.24	8.02	6.7
PA-27I	31.4	29.5	29.1	28.9	0.83	0.27	0.37	0.70	6.80	7.08	8.45	7.3
PA-27D	30.6	28.9	28.6	28.7	0.95	0.05	0.27	0.70	6.71	7.11	8.69	7.4
PA-28S	25.3	28.9	27.7	27.3	0.91	0.35	0.00	0.70	6.55	6.89	7.92	6.6
PA-28I	25.2	27.9	27.4	27.2	0.95	0.63	0.33	0.40	6.88	7.31	8.79	7.3
PA-28D	25.2	27.2	26.9	26.9	0.68	0.83	0.27	0.70	7.00	7.32	8.26	8.1
Injection and Extraction Wells												
BIW-2	26.9	28.8	27.4	27.8	0.96	0.45	0.6	0.30	6.68	7.07	8.46	6.4
BEW-2	26.3	29.3	28.0	27.6	0.79	0.7	0.22	0.23	6.49	7.27	8.06	6.5

Well ID	ORP (mV)				Conductivity (mS/cm)			
	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well								
PA-26	90	-111	-157	-245	0.21	0.12	2.46	0.28
BIO Perimeter Wells								
PA-27S	76	56	-154	-191	0.17	0.11	1.71	0.2
PA-27I	105	21	-145	-218	0.19	0.14	1.43	0.13
PA-27D	89	6	-156	-231	0.22	0.2	1.91	0.22
PA-28S	138	19	-149	-217	0.19	0.13	1.81	0.26
PA-28I	142	19	-162	-173	0.23	0.18	1.87	0.17
PA-28D	54	23	-225	-321	0.32	0.3	2.32	0.27
Injection and Extraction Wells								
BIW-2	171	-106	-111	-290	0.15	0.099	1.71	0.24
BEW-2	151	-93	-160	-301	0.17	0.076	1.08	0.23

Pre-Demo: March 2002
Dec 2002: After Electron donor was added.
Mar 2003: March 19, 2003 (approximately 2 months after the KB-1 injection)
Post-Demo: June 2003.

Table D-2. Summary of Inorganic Results in Groundwater

Well ID	Dissolved Iron (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Manganese (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Calcium (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Magnesium (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well																
PA-26	30.9	1.76	2.67	8.13	0.175	0.109	0.177	0.402	140	135	321	50.1	16.6	14.9	38.7	47
PA-26-DUP	NA	1.94	NA	8.34	NA	0.102	NA	0.406	NA	129	NA	538	NA	14	NA	49.3
BIO Perimeter Wells																
PA-27S	9.83	0.862	3.86	7.9	0.195	0.0804	0.161	0.416	120	87.7	136	249	13.6	16	19.7	34.2
PA-27I	3.1	4.06	1.32	1.19	0.406	0.0639	0.0335	0.029	140	77.8	59.5	74.4	30	90.8	74.2	105
PA-27D	4.04	2.42	0.742	0.962	0.088	0.0646	0.0357	0.0343	168	68.4	50.5	70.2	28.8	45.4	36.8	55.5
PA-28S	20	3.82	5.71	12.4	0.213	0.0485	0.0782	0.195	133	132	185	431	17.7	12.4	22.2	47.8
PA-28S-DUP	NA	NA	5.79	NA	NA	NA	0.0798	NA	NA	NA	181	NA	NA	NA	22.1	NA
PA-28I	3.15	1.72	0.886	0.502	0.091	0.0334	0.0228	0.198	53.1	49.4	41	43.9	81.8	68.4	57.4	62.9
PA-28D	2.69	1.65	3.13	<0.1	0.075	0.0274	0.154	0.09	59.1	63.8	80.6	71.1	73.3	77.4	52.6	72.7
Injection and Extraction Wells																
BIW	NA	1.16	NA	NA	NA	0.1	NA	NA	NA	88.4	NA	NA	NA	9.55	NA	NA
BIW-2	10.5	1.17	3.36	0.386	0.112	0.101	0.254	1.31	109	88.5	135	452	14.9	9.54	12.1	42.1
BEW	NA	1.2	NA	NA	NA	0.103	NA	NA	NA	82.2	NA	NA	NA	9.81	NA	NA
BEW-2	7.48	0.656	1.49	17	0.074	0.0569	0.263	1.06	129	72.3	127	386	9.63	4.95	13.3	32.9

Well ID	Potassium (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Sodium (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Chloride (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Phosphate (mg/L) Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well																
PA-26	279	43.7	45.1	50.8	46.3	64	66.3	76.1	246	172	232	311	<3.0	<0.5	<0.5	<0.5
PA-26-DUP	NA	40.5	NA	51.8	NA	60.3	NA	79.7	NA	163	NA	314	NA	<0.5	NA	<0.5
BIO Perimeter Wells																
PA-27S	176	102	90.9	69	47.4	50.8	61.4	68.6	143	99.1	213	278	<3.0	<0.5	<0.5	<0.5
PA-27I	106	31.4	28.6	38.8	96.8	51.6	45.8	52	194	169	147	142	<3.0	<0.5	<0.5	<0.5
PA-27D	51.8	29.2	23.0	32	180	273	221	270	305	397	347	393	<3.0	<0.5	<0.5	<0.5
PA-28S	146	48.1	40.8	51.7	31.7	59.6	62.1	75.8	193	182	230	325	<3.0	<0.5	<0.5	<0.5
PA-28S-DUP	NA	NA	39.2	NA	NA	NA	60.9	NA	NA	NA	242	NA	NA	NA	<0.5	NA
PA-28I	21.2	25.1	19.7	21.7	218	206	222	256	367	273	261	268	<3.0	<0.5	<0.5	<0.5
PA-28D	18.6	21.5	25.5	30.5	362	424	276	378	852	774	404	551	<3.0	<0.5	<0.5	<0.5
Injection and Extraction Wells																
BIW	NA	43	NA	NA	NA	64.8	NA	NA	NA	125	NA	NA	NA	<0.5	NA	NA
BIW-2	241	44.4	42.7	64.9	38.4	67	62	72.6	125	121	155	344	<3.0	<0.5	<0.5	1.18
BEW	NA	42.4	NA	NA	NA	60.8	NA	NA	NA	123	NA	NA	NA	<0.5	NA	NA
BEW-2	155 S	11.1	43.5	56.3	57.5	56.3	60	78.1	161	90	186	312	<3.0	<0.5	<0.5	0.22 J

Table D-2. Summary of Inorganic Results in Groundwater (Continued)

Well ID	Bromide (mg/L)				Sulfate (mg/L)				Nitrate (NO_3-NO_2 as N)				Alkalinity (mg/L)			
	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well																
PA-26	<2.0	1.06	<1	<1	172	13.7	<3	<3	NA	<0.5	<0.5	1.27	463	310	677	847
PA-26-DUP	NA	2.17	NA	<1	NA	16.4	NA	<3	NA	<0.5	NA	0.512	NA	294	NA	835
BIO Perimeter Wells																
PA-27S	<2.0	0.68 J	0.67 J	5.68	150	106	18.5	<3	NA	<0.5	<0.5	<0.5	398	230	401	469
PA-27I	<2.0	<1	<1	<1.0	292	99.5	109	101	NA	<0.5	<0.5	<0.5	344	409	327	375
PA-27D	<2.0	0.64 J	0.59 J	4.15	385	126	119	110	NA	<0.5	<0.5	1.82	261	310	314	303
PA-28S	<2.0	1.14	0.25 J	<1	100	<3	<3	<3	NA	<0.5	<0.5	<0.5	390	327	427	705
PA-28S-DUP	NA	NA	<1.0	NA	NA	NA	<3	NA	NA	NA	0.657	NA	NA	NA	425	NA
PA-28I	<2.0	1.36	0.29 J	<1	107	102	95.5	92.2	NA	<0.5	<0.5	<0.5	441	431	417	396
PA-28D	25.3	1.44	1.67	<1	73	69.2	107	11	NA	<0.5	<0.5	<0.5	262	299	242	320
Injection and Extraction Wells																
BIW	NA	1.25	NA	NA	NA	107	NA	NA	NA	<0.5	NA	NA	NA	204	NA	NA
BIW-2	<2.0	1.62	1.59	<1	128	104	74.3	<3	NA	<0.5	<0.5	<0.5	429	210	324	767
BEW	NA	0.72 J	NA	NA	NA	105	NA	NA	NA	<0.5	NA	NA	NA	206	NA	NA
BEW-2	<2.0	0.31 J	1.32	<1	141	108	75.7	1.2 J	NA	<0.5	<0.5	1.6	410	131	335	592

NA: Not analyzed.
Pre-Demo: March 2002
Dec 2002: After the addition of electron donor (ethanol).
Mar 2003: March 19, 2003 (approximately 2 months after the addition of KB-1 cultures).
Post-Demo: June 2003.

Table D-3. Other Parameter Results of Groundwater

Well ID	TDS (mg/L)				TOC (mg/L)				BOD (mg/L)		Dissolved Silica (mg/L)			
	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well														
PA-26	1,220	NA	2,110	3,000	76	NA	NA	1,050	12.0	38	23.1	NA	29.3	36.1
PA-26-DUP	NA	NA	NA	3,060	NA	NA	NA	1,040	NA	40	NA	NA	NA	35.1
BIO Perimeter Wells														
PA-27S	955	NA	984	1,320	95	NA	NA	140	<6.0	39	21.5	NA	19.2	26.0
PA-27I	1,120	NA	782	869	65	NA	NA	10	10.0	10	29.2	NA	55.3	68.0
PA-27D	1,350	NA	1,120	1,200	58	NA	NA	14.8	7.0	19	41.6	NA	48.3	50.6
PA-28S	921	NA	1,180	2,400	235	NA	NA	684	<12.0	40	28.3	NA	35.0	32.0
PA-28S-DUP	NA	NA	1,170	NA	NA	NA	NA	NA	NA	NA	NA	NA	35.5	NA
PA-28I	1,100	NA	1,010	1,000	180	NA	NA	8.08	6.0	8	56.6	NA	57.9	66.6
PA-28D	1,630	NA	1,290	1,350	53.6	NA	NA	37	<6.0	41	47.9	NA	31.6	43.4
Injection and Extraction Wells														
BIW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BIW-2	898	NA	821	2,270	31	NA	NA	572	<6.0	104	21.2	NA	17.6	31.9
BEW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BEW-2	901	NA	866	1,860	58.8	NA	NA	384	<6.0	99	14.1	NA	18.3	24.8

Pre-Demo: March 2002.
Post-Demo: June 2003.
Shading denotes substantial increases after the biostimulation/bioaugmentation treatment.

Table D-4. Results of Chloride Samples Using a Waterloo Profiler® Sampler

Sample ID	Chloride (mg/L)	Sample ID	Chloride (mg/L)
BIO Plot			
BIO-WP1-15	53.2	BIO-WP201-18	237
BIO-WP1-20	101	BIO-WP201-24	354
BIO-WP1-30	282	BIO-WP201-33	160
BIO-WP1-35	686	BIO-WP201-38	565
BIO-WP1-40	770		
BIO-WP2-15	88.2	BIO-WP202-18	276
BIO-WP2-20	166	BIO-WP202-24	287
BIO-WP2-30	226	BIO-WP202-33	144
BIO-WP2-36	733	BIO-WP202-38	678
BIO-WP2-38	783		

Table D-5. Results of Dissolved Gases in Groundwater

Well ID	Ethane (mg/L)				Ethene (mg/L)				Methane (mg/L)			
	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo	Pre-Demo	Dec 2002	Mar 2003	Post-Demo
BIO Plot Well												
PA-26	0.0247	<0.002	0.002	0.00234	0.573	0.03	2.31	22.9	0.00368	0.0139	0.023	0.137
PA-26-DUP	NA	<0.002	NA	0.0025	NA	0.0319	NA	24.3	NA	0.0125	NA	0.203
BIO Perimeter Wells												
PA-27S	0.0129	<0.002	<0.002	<0.002	0.235	0.0088	0.852	2.79	0.00739	0.0443	0.0232	0.013
PA-27I	0.00713	0.0076	0.0067	0.00483	0.107	0.141	0.0904	0.161	0.00154	0.0205	0.0233	0.0148
PA-27D	0.0148	0.0033	0.0042	0.0015 J	0.366	0.0817	0.0688	0.0743	0.00551	0.013	0.0182	0.00543
PA-28S	0.0537	0.0383	0.0695	0.036	0.235	0.123	1.78	16.3	0.0308	0.0137	0.0315	0.036
PA-28S-DUP	NA	NA	0.098	NA	NA	NA	1.96	NA	NA	NA	0.0318	NA
PA-28I	0.0142	0.0047	0.006	0.00443	0.381	0.0524	0.0526	0.0624	0.0227	0.0674	0.103	0.0686
PA-28D	0.0252	0.0066	0.0201	0.00432	0.338	0.0316	0.0492	0.0373	0.00804	0.0158	0.0177	0.0128
Injection and Extraction Wells												
BIW	NA	<0.002	NA	NA	NA	0.0083	NA	NA	NA	0.0157	NA	NA
BIW-2	0.0194	<0.002	<0.002	0.00069 J	0.00725	0.0075	0.368	14	0.0164	0.0142	0.0142	0.137
BEW	NA	<0.002	NA	NA	NA	0.0084	NA	NA	NA	0.015	NA	NA
BEW-2	0.00801	<0.002	0.0042	0.0159	0.0289	<0.003	1.14	16.2	0.00795	0.011	0.0277	0.214

NA: Not available.
Pre-Demo: March 2002.
Dec 2002: After Electron donor was added.
Mar 2003: March 19, 2003 (approximately 2 months after the addition of KB-1 cultures).
Post-Demo: June 2003.
Shading denotes substantial increases after the biostumulation/bioaugmentation treatment.

Table D-6. Results of TOC in Soil Samples Collected in Bioaugmentation Plot

Sample ID	TOC Results (wt%-dry)	Sample ID	TOC Results (wt%-dry)
BIO-SB2-16	0.05	BIO-SB205-18	0.09
BIO-SB2-34	0.13	BIO-SB205-26	0.13
BIO-SB2-38	0.20	BIO-SB205-34	0.21
BIO-SB4-18	0.06	BIO-SB205-42	0.15
BIO-SB4-34	0.14	BIO-SB207-12	0.15
BIO-SB4-40	0.22	BIO-SB207-20	0.06
		BIO-SB207-32	0.14
		BIO-SB207-40	0.25

Appendix E

Genetrac Analysis of Groundwater Samples from the Bioaugmentation Demonstration

SAMPLING AND SHIPPING PROTOCOL FOR GENE-TRAC *DEHALOCOCCOIDES* TESTING

Sample Containers:

Clean, new, wide-mouth screw cap 1-liter (L) high-density polyethylene (HDPE) bottles (e.g., Nalgene or equivalent) should be used for Gene-Trac samples. Pre-cleaned, 40-milliliter (mL) volatile organic analysis (VOA) vials should be used for "companion" volatile organic compound (VOC) samples. For your convenience, SiREM can ship appropriate containers to your location at cost. Please allow three business days notice for this service.

Sample Collection:

Groundwater samples should not be collected until oxidation/reduction potential (ORP) measurements of the purged water stabilizes to within about 10% of the previous reading. Turbidity in the Gene-Trac samples is desirable as it increases the likelihood of capturing microorganisms. Two 1L groundwater samples should be collected from each well for Gene-Trac analysis. Samples should be collected without headspace or preservatives. In addition, two 40 mL VOA vials (with HCl as preservative) for each sample location should be included for companion VOC analysis.

Quality Assurance/Quality Control (QA/QC):

Gene-Trac testing is extremely sensitive, so care must be taken to prevent contamination of the samples with any foreign material, including groundwater from other sampling points. QA/QC samples consist of field blanks and equipment blanks (if non-dedicated equipment is used). A field blank is used to determine if sample contamination in the field or in transit has occurred. The field blank consists of 1L of commercially available distilled water (customer to provide) placed in a 1.0 L sample bottle at one sampling location. Where non-dedicated sampling equipment is used, equipment should be thoroughly decontaminated between sampling locations using standard procedures for VOC analysis. An equipment blank should be prepared by passing distilled water through non-dedicated equipment after the cleaning process, to determine if decontamination procedures were effective.

Sample Custody, Shipping and Handling:

Samples should be clearly labeled and individually sealed in re-sealable freezer bags then placed in a plastic cooler with cool packs (not ice). Ship the samples priority overnight courier under chain-of-custody to SiREM for analysis. Label samples on waybill "groundwater samples to be destroyed upon analysis". **Samples should be given a value of $1, otherwise 15% duty will be applied to the stated value (to be paid by client).** No special regulations apply to the shipping of groundwater samples to Canada. Holding time for Gene-Trac samples is 28 days at 4 degrees C.

Send Coolers to:

SiREM Laboratory
130 Research Lane, Suite 2
Guelph, Ontario
Canada, N1G 5G3

Direct Inquiries to:

Phil Dennis
Phone: 1-877-279-6832/519-822-2265 ext. 238
Fax: 519-822-3151
E-mail: pdennis@siremlab.com

130 Research Lane Guelph, Ontario, Canada, N1G 5G3
Telephone: (519)-822-2230 Fax: (519)-822-3151 E-mail: pdennis@geosyntec.com

Gene-Trac™ *Dehalococcoides* Test, Case Narrative, Test DT-0003

Six groundwater samples from the NASA launch complex 34 were analyzed for the presence of *Dehalococcoides* using the Gene-Trac™ method. The test was performed on three separate occasions using two separate DNA extractions. The test was replicated due to the fact that the results, while positive, tended to be weakly so and not positive with all primer sets used. This may reflect the type of *Dehalococcoides* organism present, which may not have gene sequences that bind all primers efficiently. This is why we include several primer sets in the assay to ensure that a maximum diversity of *Dehalococcoides* organisms are detectable. For sample PA-26S it was impossible to extract PCR amplifiable DNA, based on the lack of amplification with a non-*Dehalococcoides* specific PCR primer set. This suggests that while *Dehalococcoides* was not present in this sample no significant amounts of any other *Bacteria* were detected either. Please note that the high "Intensity % of positive control" and "Band Intensity Score" for sample IW-1I may not actually indicate high concentrations of *Dehalococcoides* at this location, relative to the other locations. The "++++" result for this sample arose because the band intensity score is determined relative to the positive control, which was relatively weak in the positive control for the primer set that worked for this sample.

PD

SiREM *Dehalococcoides* Testing Service, 130 Research Lane Guelph, Ontario, Canada, N1G 5G3
Telephone: (519)-822-2230 Fax: (519)-822-3151 E-mail: pdennis@geosyntec.com

Test Results for Gene-Trac™ *Dehalococcoides* Assay

Test Particulars:

Client Name: Battelle	**Test Reference Number:** DT-0003
Contact: Sam Yoon	**Date Report Issued:** May 15, 2002
Site Location: NASA LC34	**Date Sample(s)Received:** April 1/2002
Telephone: (614) 424-4569	**Method Used:** GeneTrac™ *Dehalococcoides* Assay
E-mail: yoon@Battelle.org	**Positive Control (Pos. Ctrl.):** Assay with Cloned *Dehalococcoides* 16S rRNA gene
Fax: (614) 458-4569	**Negative Control (Neg. Ctrl):** DNA extraction with sterile water

Test Results:

Client Sample ID	Site Sampling Date	SiREM ID	DNA Extraction Date	Intensity % of Positive Control	Band Intensity Score	Comments
PA-26S	3/29/2002	DHC-0022	4/19/2002	0%	-	*Dehalococcoides* not detected (no DNA in sample)
PA-27S	3/29/2002	DHC-0023	4/19/2002	4.2%	+	*Dehalococcoides* detected
PA-27I	3/29/2002	DHC-0024	4/19/2002	5.4%	+	*Dehalococcoides* detected
PA-28S	3/29/2002	DHC-0025	4/19/2002	14%	+	*Dehalococcoides* detected
PA-28I	3/29/2002	DHC-0026	4/19/2002	10%	+	*Dehalococcoides* detected
IW-1I	3/29/2002	DHC-0027	4/19/2002	141%	++++	*Dehalococcoides* detected
na	na	Pos. Ctrl.	na	100%	+++	Normal
na	na	Neg. Ctrl	na	0%	-	Normal

The above results refer only to that portion of the sample tested with the Gene-Trac assay. The test is based on PCR with primer sets specific to DNA sequences in the 16S rRNA gene of *Dehalococcoides*. A positive (+) result in this assay indicates that a member of the *Dehalococcoides* group was detected in the water sample. *Dehalococcoides* organisms are the only microorganisms proven to possess the necessary enzymes for the complete dechlorination of PCE or TCE to ethene. The presence of *Dehalococcoides* has been positively correlated to complete dechlorination of chlorinated ethenes at contaminated sites.

*Band Intensity Score, categorizes PCR product quantity based on the "intensity % of positive control": ++++ = Very high band intensity (greater than 100% of positive control), +++ = high band intensity (67-100%), ++ = moderate band intensity (34 -66%) + = low band intensity (4 - 33%), -/+ = inconclusive (1-3%), - = no band (0%)

"Intensity % of Positive control" = Quantitative assessment of electrophoresis gel band intensity of combined test results as a percentage of positive control reaction. This value provides a semi-quantitative assessment of the number of *Dehalococcoides* organisms present in the sample. While band intensity might reflect actual concentration of the target organism, GeneTrac™ is a semi-quantitative method and results are only guaranteed to be a qualitative indicator for determination of the presence or absence of *Dehalococcoides*.

Authorized by: ____

Philip Dennis, M.A.Sc., SiREM Operations Manager

130 Research Lane, Suite 2 Guelph, Ontario, N1G 5G3 Canada Tel: (519) 822-2265 Fax: (519) 822-3151

Test Results for Gene-Trac *Dehalococcoides* Assay

Client Name: Battelle	**Test Reference Number:** DT-0095
Contact: Sam Yoon	**Report Issued:** 11-Jul-03
Site Location: NASA LC34	**Site Sampling:** 23-Jun-03 **Sample(s) Received**:25-Jun-03 **DNA Extraction**: 25-Jun-03
Telephone: (614) 424-4569	**Gel Image Number :** DHC-UP-0050/AG-0117
E-mail: yoon@BATTELLE.ORG]	**Positive Control (+ve control):** Assay with Cloned *Dehalococcoides* 16S rRNA gene
Fax: (614) 458-4569	**Negative Control (-ve control):** Assay with DNA extraction blank

Test Results:

Client Sample ID	**SiREM ID**	**Non-*Dehalococcoides* Bacterial DNA**	***Dehalococcoides* Test, Intensity** (% of Positive Control)	**Intensity Score**	**Test Result: *Dehalococcoides* DNA**
BIO-PA26-062303	DHC-0492	Not Detected	106%	++++	Detected (3 of 3 primer sets)
PA-26S(A) (sampled 3/29/2002)	DHC-0022	Not Detected	3%	-/+	Inconclusive (1 of 3 primer sets)
Not applicable	+ve control	Not applicable	100%	+++	Detected (3 of 3 primer sets)
Not applicable	-ve control	Not applicable	0%	-	Not Detected

The above results refer only to that portion of the sample tested with the Gene-Trac assay. The test is based on a polymerase chain reaction (PCR) test with three primer sets specific to DNA sequences in the 16S rRNA gene of *Dehalococcoides* organisms. A positive (+ to ++++) result indicates that genetic material (DNA) from a member of the *Dehalococcoides* group was detected. *Dehalococcoides* organisms are the only microorganisms proven to possess the necessary enzymes for the complete dechlorination of tetrachloroethene or trichloroethene to ethene. The presence of *Dehalococcoides* genetic material has been positively correlated to complete dechlorination of chlorinated ethenes at contaminated sites.

"Dehalococcoides Test Intensity" = quantitative assessment of electrophoresis band intensity of PCR product as a percentage of the corresponding positive control reaction. This value provides a semi-quantitative assessment of the amount of *Dehalococcoides* genetic material present in the sample. While band intensity might reflect actual concentration of the target organism, Gene-Trac is a semi-quantitative method and is only recommended to determine the presence or absence of *Dehalococcoides* genetic material in the sample.

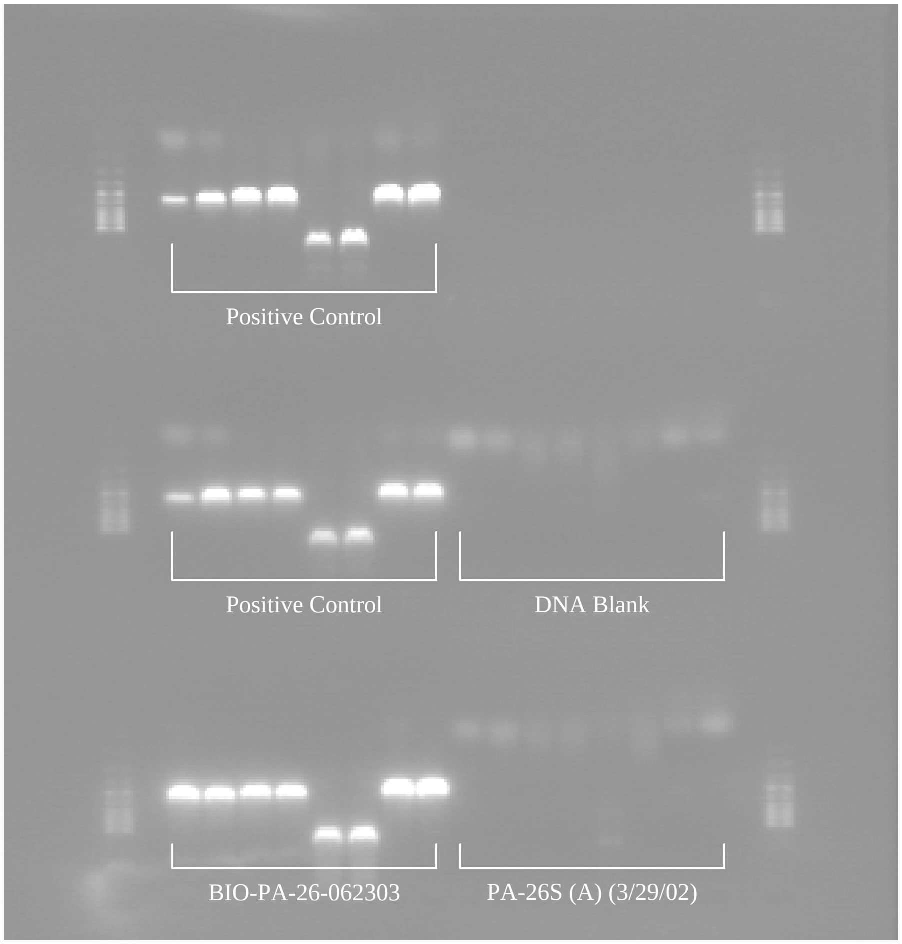
"Intensity Score", categorizes PCR product quantity based on the "intensity (% of positive control)": ++++ = Very high band intensity (greater than 100% of positive control), +++ = high band intensity (67-100%), ++ moderate band intensity (34-66%) + = low band intensity (4-33%), -/+ = inconclusive (1-3%), - = no detectable band (0%)

Analyst: ________________________ **Authorized by:** ________________________ **Date:** ____________

Jaimee Mariani, Laboratory Technologist

Philip Dennis, M.A.Sc., Director, SiREM

DT-0095 AG-0117C – Battelle Gene-Trac Gel Image



Appendix F

Quality Assurance/Quality Control Information

Table F-1. Results of the Extraction Procedure Performed on PA-4 Soil Samples

Extraction Procedure Conditions	Combined
Total Weight of Wet Soil (g) = 2,124.2	1,587.8 g dry soil from PA-4 boring
Concentration (mg TCE/g soil) = 3.3	529.3 g deionized water
Moisture Content of Soil (%) = 24.9	5 mL TCE

Laboratory Extraction Sample ID	TCE Concentration in MeOH (mg/L)	TCE Mass in MeOH (mg)	TCE Concentration in Spiked Soil (mg/kg)	Theoretical TCE Mass Expected in MeOH (mg)	Percentage Recovery of Spiked TCE (%)
1st Extraction procedure on same set of samples					
SEP-1-1	1800.0	547.1	3252.5	744.11	73.53
SEP-1-2	1650.0	501.8	3164.9	701.26	71.55
SEP-1-3	1950.0	592.2	3782.3	692.62	85.51
SEP-1-4	1840.0	558.1	3340.2	739.13	75.51
SEP-1-5	1860.0	564.0	3533.9	705.91	79.89
SEP-1-6 (Control)	78.3	19.4	-	25.00	77.65
				Average % Recovery =	77.20
2nd Extraction procedure on same set of samples					
SEP-2-1	568.0	172.7	861.1	887.28	19.47
SEP-2-2	315.0	95.5	500.5	843.77	11.31
SEP-2-3	170.0	51.3	268.2	846.42	6.06
SEP-2-4	329.0	99.8	498.4	885.29	11.27
SEP-2-5	312.0	94.8	476.3	880.31	10.77
SEP-2-6 (Control)	82.6	20.4	-	25.00	81.79
				Average % Recovery =	11.78
3rd Extraction procedure on same set of samples					
SEP-3-1	55.8	17.0	84.6	885.96	1.91
SEP-3-2	59.0	17.9	94.2	841.77	2.13
SEP-3-3	56.8	17.2	90.1	846.42	2.04
SEP-3-4	63.0	19.1	95.2	888.61	2.15
SEP-3-5	52.2	15.8	80.0	875.99	1.81
SEP-3-6 (Control)	84.3	20.9	-	25.00	83.55
				Average % Recovery =	2.01

Table F-2. 1,1,1-TCA Surrogate Spike Recovery Values for Soil Samples Collected During the Bioaugmentation Demonstration Characterization

Bioaugmentation Treatment Plot 1,1,1 TCA-Spiked Soil Samples QA/QC Target Level RPD < 30.0 %					**Total Number of Soil Samples Collected = 230 [Pre-(139); Post-(91)] Total Number of Spiked Samples Analyzed = 7 (Pre-) 6 (Post-)**				
Sample ID	**Sample Date**	**1,1,1-TCA Result (ug/L)**	**RPD (%)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**1,1,1-TCA Result (ug/L)**	**RPD (%)**	**Met QA/QC Criteria?**
Pre-Demonstration					***Post-Demonstration***				
BIO-SB1-8(SS)	01/14/02	5,680	9.56	Yes	BIO-SB202-42(SS)	06/17/03	4,900	ND	No
BIO-SB1-MB(SS)		6,250			BIO-SB202- MB(SS)		NC		
BIO-SB2-8(SS)	01/23/02	6,360	4.31	Yes	BIO-SB205-42(SS)	06/18/03	5,100	ND	No
BIO-SB2-MB(SS)		6,640			BIO-SB205- MB(SS)		NC		
BIO-SB3-8(SS)	01/23/02	7,210	0.696	Yes	BIO-SB206-40(SS)	06/19/03	5,180	ND	No
BIO-SB3-MB(SS)		7,160			BIO-SB206- MB(SS)		NC		
BIO-SB4-8(SS)	01/24/02	6,480	11.63	Yes	BIO-SB207-40(SS)	06/20/03	5,430	ND	No
BIO-SB4-MB(SS)		7,280			BIO-SB207- MB(SS)		NC		
BIO-SB5-8(SS)	02/04/02	4,870	6.17	Yes	BIO-SB210-30(SS)	06/18/03	5,920	ND	No
BIO-SB5-MB(SS)		5,180			BIO-SB210- MB(SS)		NC		
BIO-SB6-8(SS)	02/05/02	5,560	17.40	Yes	BIO-SB211-30(SS)	06/19/03	5,170	ND	No
BIO-SB6-MB(SS)		6,620			BIO-SB211- MB(SS)		NC		
BIO-SB7-8(SS)	02/06/02	4,970	14.45	Yes					
BIO-SB7-MB(SS)		4,300							

NC=Not collected due to field error.
ND = Not determined.

Table F-3. Results and Precision of the Field Duplicate Samples Collected During the Pre- and Post-Demonstration Soil Sampling

Bioaugmentation Treatment Plot Field Duplicate Soil Samples QA/QC Target Level RPD < 30.0 %					**Total Number of Soil Samples Collected = 230 [Pre-(139); Post-(91)] Total Number of Field Duplicate Samples Analyzed = 7 (Pre-) 6 (Post-)**				
Sample ID	**Sample Date**	**TCE Result (mg/kg)**	**RPD (%)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**TCE Result (mg/kg)**	**RPD (%)**	**Met QA/QC Criteria?**
Pre-Demonstration					***Post-Demonstration***				
BIO-SB1-22	01/14/02	21	33.33	No	BIO-SB202-20	06/17/03	Trace	0.0	Yes
BIO-SB1-22 DUP		15			BIO-SB202-20 DUP		Trace		
BIO-SB2-14	01/23/02	13	0.0	Yes	BIO-SB205-16	06/18/03	Trace	0.0	Yes
BIO-SB2-14 DUP		13			BIO-SB205-16 DUP		Trace		
BIO-SB3-18	01/23/02	8	122(b)	No	BIO-SB206-22	06/19/03	Trace	0.0	Yes
BIO-SB3-18 DUP		33			BIO-SB206-22 DUP		Trace		
BIO-SB4-42	01/24/02	Trace	0.0	Yes	BIO-SB207-28	06/20/03	118	17.76	Yes
BIO-SB4-42 DUP		Trace			BIO-SB207-28 DUP		141		
BIO-SB5-38	02/04/02	308	14.26	Yes	BIO-SB210-20	06/18/03	1	200(a)	No
BIO-SB5-38 DUP		287			BIO-SB210-20 DUP		0		
BIO-SB6-28	02/05/02	420	15.11	Yes	BIO-SB211-24	06/19/03	1	200(a)	No
BIO-SB6-28 DUP		361			BIO-SB211-24 DUP		0		
BIO-SB7-22	02/06/02	15	6.90	Yes					
BIO-SB7-22 DUP		14							

(a) High RPD value due to the effect of low (or below detect) concentrations of TCE, which drastically affected the RPD calculation.
(b) High RPD value may be due to high levels of DNAPL distributed heterogeneously through the soil core sample.

Table F-4. Results of the Rinsate Blank Samples Collected During the Pre- and Post-Demonstration Soil Sampling

Bioaugmentation Rinsate Blank Soil Extraction QA/QC Samples QA/QC Target Level TCE < 1.0 ug/L				Total Number of Soil Samples Collected = 230 [Pre-(139); Post-(91)] Total Number of Field Samples Analyzed = 9			
Sample ID	**Sample Date**	**TCE Result (ug/L)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**TCE Result (ug/L)**	**Met QA/QC Criteria?**
Pre-Demonstration Rinsate Blank Samples				***Post-Demonstration Rinsate Blank Samples***			
BIO-SB1-RINSATE	01/14/02	<1.0	Yes	BIO-SB202-RINSATE	06/17/03	<1.0	Yes
BIO-SB2-RINSATE	01/23/02	<1.0	Yes	BIO-SB205-RINSATE	06/18/03	2.58	No
BIO-SB3-RINSATE	01/24/02	<1.0	Yes	BIO-SB206-RINSATE	06/19/03	4.53	No
BIO-SB6-RINSATE	02/05/02	<1.0	Yes	BIO-SB207-RINSATE	06/20/03	<1.0	Yes
BIO-SB7-RINSATE	02/06/02	<1.0	Yes				

Table F-5. Results of the Methanol Blank Samples Collected During the Pre- and Post-Demonstration Soil Sampling

Bioaugmentation Methanol Blank Soil Extraction QA/QC Samples QA/QC Target Level < 100 ug/L				**Total Number of Soil Samples Collected = 230 [Pre-(139); Post-(91)] Total Number of Methanol Blank Samples Analyzed = 13**			
Sample ID	**Sample Date**	**TCE Result (ug/L)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**TCE Result (ug/L)**	**Met QA/QC Criteria?**
Pre-Demonstration Methanol Blank Samples				***Post-Demonstration Methanol Blank Samples***			
BIO-SB1-MEOH	01/14/02	<100	Yes	BIO-SB202-MEOH	06/17/03	<100	Yes
BIO-SB2-MEOH	01/23/02	177	No	BIO-SB205-MEOH	06/18/03	<100	Yes
BIO-SB3-MEOH	01/23/02	<100	Yes	BIO-SB206-MEOH	06/19/03	<100	Yes
BIO-SB4-MEOH	01/24/02	<100	Yes	BIO-SB207-MEOH	06/20/03	<100	Yes
BIO-SB5-MEOH	02/04/02	<100	Yes	BIO-SB210-MEOH	06/18/03	<100	Yes
BIO-SB6-MEOH	02/05/02	<100	Yes	BIO-SB211-MEOH	06/19/03	<100	Yes
BIO-SB7-MEOH	02/06/02	<100	Yes				

Table F-6. Results and Precision of the Field Duplicate Samples Collected During the Bioaugmentation Demonstration Groundwater Sampling Events

Bioaugmentation Treatment Plot Groundwater QA/QC QA/QC Target Level RPD < 30.0 %		Total Number of Groundwater Samples Collected = 43 [Pre- (9); During (24); Post- (10)] Total Number of Field Duplicate Samples Analyzed = 3		
Sample ID	**Sample Date**	**TCE Result (ug/L)**	**RPD (%)**	**Met QA/QC Criteria?**
Bioaugmentation Pre-Demonstration Field Duplicate Samples				
PA-26	03/26/02	1,180,000	ND	No
PA-26-DUP		NC		
First Sampling Event During the Bioaugmentation Demonstration				
PA-26	12/12/02	7,460	3.83	Yes
PA-26-DUP	12/12/02	7,180		
Second Sampling Event During the Bioaugmentation Demonstration				
PA-28S	3/20/03	68,200	21.06	Yes
PA-28S-DUP	3/20/03	55,200		
Bioaugmentation Post-Demonstration Field Duplicate Samples				
PA-26[(a)]	06/23/03	239	40.81	No
PA-26-DUP[(a)]	06/23/03	158		

NC = Not collected due to field error.
ND = Not determined.
(a) High RPD value due to the effect of low (or below detect) concentrations of TCE, which drastically affected the RPD calculation.

Table F-7. Results of the Rinsate Blank Samples Collected During the Bioaugmentation Demonstration Groundwater Sampling Events

Bioaugmentation Groundwater QA/QC Samples QA/QC Target Level TCE < 3.0 ug/L	**Total Number of Samples Collected = 43 [Pre- (9); During- (24); Post- (10)] Total Number of Rinsate Blank Samples Analyzed = 4**		
Sampling Event	**Analysis Date**	**TCE Concentration (ug/L)**	**Met QA/QC Criteria?**
Pre-Demonstration	03/27/02	<1.0	Yes
First Sampling Event During the Demonstration	12/12/02	<1.0	Yes
Second Sampling Event During the Demonstration	03/20/03	<1.0	Yes
Post-Demonstration	06/24/03	1.48	Yes

Table F-8. Results of the Trip Blank Samples Analyzed During the Bioaugmentation Demonstration Soil and Groundwater Sampling

Bioaugmentation Trip Blank QA/QC Samples QA/QC Target Level TCE < 3.0 ug/L				**Total Number of Samples Collected = 230 (Soil) 43 (Groundwater) Total Number of Trip Blanks Analyzed = 18**			
Sample ID	**Sample Date**	**TCE Result (ug/L)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**Result (ug/L)**	**Met QA/QC Criteria?**
Bioaugmentation Demonstration Trip Blanks							
BIO-TB-1	01/16/02	<1.0	Yes	BIO-TB-10	06/19/03	<1.0	Yes
BIO-TB-2	01/24/02	<1.0	Yes	BIO-TB-11	06/20/03	<1.0	Yes
BIO-TB-3	01/24/02	<1.0	Yes	BIO-TB-12	03/27/02	<1.0	Yes
BIO-TB-4	01/25/02	<1.0	Yes	BIO-TB-13	03/28/02	<1.0	Yes
BIO-TB-5	02/04/02	<1.0	Yes	BIO-TB-14	12/12/02	<1.0	Yes
BIO-TB-6	02/05/02	<1.0	Yes	BIO-TB-15	12/12/02	<1.0	Yes
BIO-TB-7	02/07/02	<1.0	Yes	BIO-TB-16	03/20/03	<1.0	Yes
BIO-TB-8	02/08/02	<1.0	Yes	BIO-TB-17	06/23/03	<1.0	Yes
BIO-TB-9	06/18/03	<1.0	Yes	BIO-TB-18	06/24/03	1.41	Yes

Table F-9. Matrix Spike Sample Analysis for the Bioaugmentation Pre-Demonstration Soil Sampling Events

Bioaugmentation Demonstration Soil MS/MSD Samples **QA/QC Target Level Recovery % = 70 – 130 %** **QA/QC Target Level RPD < 30.0 %**	**Total Number of Samples Collected = 230 [Pre- (139); Post- (91)]** **Total Number of Matrix Spike Samples Analyzed = 19** **Total Number of Matrix Spike Duplicate Samples Analyzed = 19**

Sample ID	Sample Date	TCE Recovery (%)	Met QA/QC Criteria?	RPD (%)	Met QA/QC Criteria?	Sample ID	Sample Date	TCE Recovery (%)	Met QA/QC Criteria?	RPD (%)	Met QA/QC Criteria?
Bioaugmentation Pre-Demonstration Matrix Spike Samples											
0201067-03A MS	01/18/02	103	Yes	0.054	Yes	0201112-05A MS	1/29/02	110	Yes	1.27	Yes
0201067-03A MSD		103	Yes			0201112-05A MSD		109	Yes		
0201067-26A MS	01/19/02	101	Yes	1.97	Yes	0202015-04A MS	02/05/02	118	Yes	0.95	Yes
0201067-26A MSD		103	Yes			0202015-04A MSD		119	Yes		
0201067-49A MS	01/21/02	121	Yes	0.446	Yes	0202016-04A MS	02/06/02	116	Yes	2.36	Yes
0201067-49A MSD		121	Yes			0202016-04A MSD		119	Yes		
0201067-60A MS	01/22/02	103	Yes	5.47	Yes	0202024-14A MS	02/06/02	108	Yes	0.51	Yes
0201067-60A MSD		90	Yes			0202024-14A MSD		109	Yes		
0201067-15A MS[a]	01/22/02	-52.4	No	0.712	Yes	0202024-15A MS	02/07/02	110	Yes	1.27	Yes
0201067-15A MSD[a]		-53.2	No			0202024-15A MSD		109	Yes		
0201105-01A MS[a]	01/26/02	33.9	No	0.556	Yes	0202034-10A MS	02/08/02	101	Yes	1.27	Yes
0201105-01A MSD[a]		26.5	No			0202034-10A MSD		102	Yes		
0201105-09A MS	01/28/02	113	Yes	0.169	Yes	0202035-04A MS	02/09/02	104	Yes	2.55	Yes
0201105-09A MSD		112	Yes			0202035-04A MSD		102	Yes		
0201104-04A MS	01/29/02	110	Yes	2.46	Yes	0202037-10A MS	02/12/02	121	Yes	0.909	Yes
0201104-04A MSD		113	Yes			0202037-10A MSD		120	Yes		
0201104-50A MS	01/29/03	109	Yes	4.77	Yes	0202037-09A MS	02/13/02	130	Yes	21.5	Yes
0201104-50A MSD	01/30/03	103	Yes			0202037-09A MSD		162	No		
0201104-27A MS	01/30/02	97.8	Yes	1.79	Yes						
0201104-27A MSD		95.9	Yes								

(a) Spike recovery was outside of the control limits due to the high concentration of TCE present in the reference sample. No further corrective actions were required and no sample results were adversely affected.

Table F-10. Matrix Spike Sample Analysis for the Bioaugmentation Post-Demonstration Soil Sampling Events

Bioaugmentation Demonstration Soil MS/MSD Samples QA/QC Target Level Recovery % = 70 – 130 % QA/QC Target Level RPD < 30.0 %						Total Number of Samples Collected = 230 [Pre- (139); Post- (91)] Total Number of Matrix Spike Samples Analyzed = 10 Total Number of Matrix Spike Duplicate Samples Analyzed = 10					
Sample ID	**Sample Date**	**TCE Recovery (%)**	**Met QA/QC Criteria?**	**RPD (%)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**TCE Recovery (%)**	**Met QA/QC Criteria?**	**RPD (%)**	**Met QA/QC Criteria?**
Bioaugmentation Post-Demonstration Matrix Spike Samples											
0306097-02A MS	06/21/03	110	Yes	0.239	Yes	0306103-03A MS[a]	06/25/03	139	No	3.70	Yes
0306097-02A MSD		111	Yes			0306103-03A MSD[a]		125	Yes		
0306097-01A MS	06/21/03	113	Yes	0.518	Yes	0306103-21A MS	06/26/03	113	Yes	0.209	Yes
0306097-01A MSD		114	Yes			0306103-21A MSD		113	Yes		
0306097-39A MS	06/22/03	111	Yes	2.33	Yes	0306112-25A MS[a]	06/27/03	-2060	No	164	No
0306097-39A MSD		113	Yes			0306112-25A MSD[a]		-40.3	No		
0306112-01A MS	06/26/03	115	Yes	1.26	Yes	0306112-10A MS[a]	06/30/03	73.2	No	1.97	Yes
0306112-01A MSD		113	Yes			0306112-10A MSD[a]		68.9	No		
0306097-07A MS	07/02/03	113	Yes	5.46	Yes	0306116-03A MS	06/30/03	117	Yes	6.93	Yes
0306097-07A MSD		107	Yes			0306116-03A MSD		109	Yes		

(a) Spike recovery was outside of the control limits due to the high concentration of TCE present in the reference sample. No further corrective actions were required and no sample results were adversely affected.

Table F-11. Laboratory Control Spike Sample Analysis During the Bioaugmentation Pre-and Post Demonstration Soil Sampling Events

Bioaugmentation Demonstration Soil LCS Samples **QA/QC Target Level TCE Recovery % = 70 – 130 %**				**Total Number of Samples Collected = 230 [Pre- (139); Post- (91)]** **Total Number of Laboratory Control Spike Samples Analyzed = 37**			
Sample ID	**Sample Date**	**TCE Recovery (%)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**TCE Recovery (%)**	**Met QA/QC Criteria?**
Pre-Demonstration Laboratory Control Spike Samples							
LCS-9593	01/18/02	95.5	Yes	LCS-9662	01/28/02	90.2	Yes
LCS-9598	01/19/02	101	Yes	LCS-9665	01/29/02	112	Yes
LCS-9604	01/21/02	116	Yes	LCS-9668	01/29/02	113	Yes
LCS-9608	01/22/02	90.6	Yes	LCS-9676	01/30/02	96.5	Yes
LCS-9620	01/23/02	95.6	Yes	LCS-9673	01/29/02	102	Yes
LCS-9634	01/22/02	101	Yes	LCS-9724	02/05/02	113	Yes
LCS-9635	01/23/02	94.5	Yes	LCS-9730	02/06/02	118	Yes
LCS-9637	01/24/02	95.5	Yes	LCS-9733	02/06/02	110	Yes
LCS-9647	01/25/02	92	Yes	LCS-9736	02/07/02	111	Yes
LCS-9649	01/25/02	110	Yes	LCS-9745	02/08/02	104	Yes
LCS-9650	01/27/02	103	Yes	LCS-9758	02/08/02	108	Yes
LCS-9651	01/26/02	90.6	Yes	LCS-9772	02/11/02	121	Yes
LCS-9656	01/28/02	122	Yes	LCS-9788	02/13/02	123	Yes
Post-Demonstration Laboratory Control Spike Samples							
LCS-13557	06/20/03	109	Yes	LCS-13595	06/25/03	118	Yes
LCS-13558	06/21/03	112	Yes	LCS-13601	06/26/03	116	Yes
LCS-13559	06/21/03	115	Yes	LCS-13613	06/27/03	108	Yes
LCS-13601	06/26/03	116	Yes	LCS-13623	06/29/03	119	Yes
LCS-13659	07/01/03	114	Yes	LCS-13628	06/30/03	117	Yes
LCS-13578	06/24/03	113	Yes				

Table F-12. Method Blank Sample Analysis during the Bioaugmentation Pre- and Post-Demonstration Soil Sampling Events

Bioaugmentation Demonstration Soil QA/QC Samples QA/QC Target Level TCE < 3.0 ug/L				Total Number of Samples Collected = 230 [Pre- (139); Post- (91)] Total Number of Method Blank Samples Analyzed = 37			
Sample ID	**Sample Date**	**TCE Recovery (ug/L)**	**Met QA/QC Criteria?**	**Sample ID**	**Sample Date**	**TCE Recovery (ug/L)**	**Met QA/QC Criteria?**
Pre-Demonstration Method Blank Samples							
MB-9593	01/18/02	<1.0	Yes	MB-9662	01/28/02	<1.0	Yes
MB-9598	01/19/02	<1.0	Yes	MB-9665	01/29/02	<1.0	Yes
MB-9604	01/21/02	<1.0	Yes	MB-9668	01/29/02	<1.0	Yes
MB-9608	01/22/02	<1.0	Yes	MB-9676	01/30/02	<1.0	Yes
MB-9620	01/23/02	<1.0	Yes	MB-9673	01/29/02	<1.0	Yes
MB-9634	01/22/02	<1.0	Yes	MB-9724	02/05/02	<1.0	Yes
MB-9635	01/23/02	<1.0	Yes	MB-9730	02/06/02	<1.0	Yes
MB-9637	01/24/02	<1.0	Yes	MB-9733	02/06/02	<1.0	Yes
MB-9647	01/25/02	<1.0	Yes	MB-9736	02/07/02	<1.0	Yes
MB-9649	01/25/02	<1.0	Yes	MB-9745	02/08/02	<1.0	Yes
MB-9650	01/27/02	<1.0	Yes	MB-9758	02/08/02	<1.0	Yes
MB-9651	01/26/02	<1.0	Yes	MB-9772	02/11/02	<1.0	Yes
MB-9656	01/28/02	<1.0	Yes	MB-9788	02/13/02	<1.0	Yes
Post-Demonstration Method Blank Samples							
MB-13557	06/20/03	<1.0	Yes	MB-13595	06/26/03	<1.0	Yes
MB-13558	06/21/03	<1.0	Yes	MB-13601	06/26/03	<1.0	Yes
MB-13559	06/21/03	<1.0	Yes	MB-13613	06/27/03	<1.0	Yes
MB-13601	06/26/03	<1.0	Yes	MB-13623	06/29/03	<1.0	Yes
MB-13659	07/02/03	<1.0	Yes	MB-13628	06/30/03	<1.0	Yes
MB-13578	06/24/03	<1.0	Yes				

Table F-13. Matrix Spike Sample Analysis During the Bioaugmentation Demonstration Groundwater Sampling Events

Bioaugmentation Demonstration Groundwater QA/QC **QA/QC Target Level TCE Recovery % = 75 – 125 %** **QA/QC Target Level RPD < 20.0 %**			**Total Number of Samples Collected = 43** **[Pre- (9); During (24); Post- (10)]** **Total Number of Matrix Spike Samples Analyzed = 8** **Total Number of Matrix Spike Duplicate Samples Analyzed = 8**		
Sample ID	**Sample Date**	**TCE Recovery (%)**	**Met QA/QC Criteria?**	**RPD (%)**	**Met QA/QC Criteria?**
Bioaugmentation Pre-Demonstration Matrix Spike Samples					
0203133-20A MS	03/29/02	99.1	Yes	0.995	Yes
0203133-20A MSD		100	Yes		
0203155-06A MS[(a)]	04/04/02	14.1	No	5.25	Yes
0203155-06A MSD[(a)]		-47.2	No		
First Sampling Event During the Bioaugmentation Demonstration					
0212061-01A MS	12/18/02	99.3	Yes	4.94	Yes
0212061-01A MSD		94.5	Yes		
0212068-09A MS	12/17/02	80.9	Yes	3.17	Yes
0212068-09A MSD		78.3	Yes		
Second Sampling Event During the Bioaugmentation Demonstration					
0303107-11A MS	03/24/03	109	Yes	4.65	Yes
0303107-11A MSD		104	Yes		
Bioaugmentation Post-Demonstration Matrix Spike Samples					
0306112-10A MS[(a)]	06/30/03	73.2	No	1.97	Yes
0306112-10A MSD[(a)]		68.9	No		
0306116-03A MS	06/30/03	117	Yes	6.93	Yes
0306116-03A MSD		109	Yes		
0306097-07A MS	07/02/03	113	Yes	5.46	Yes
0306097-07A MSD		107	Yes		

(a) Matrix spike (MS) and matrix spike duplicate (MSD) were outside of the control limits due to the high concentration of TCE present in the reference sample. No further corrective actions were required and no sample results were adversely affected.

Table F-14. Laboratory Control Spike Sample Analysis During the Bioaugmentation Demonstration Groundwater Sampling Events

Bioaugmentation Demonstration Groundwater QA/QC **QA/QC Target Level TCE Recovery % = 75 – 125 %**		**Total Number of Samples Collected = 43** **[Pre- (9); During (24); Post- (10)]** **Total Number of Matrix Spike Samples Analyzed =8**	
Sample ID	**Sample Date**	**TCE Recovery (%)**	**Met QA/QC Criteria?**
Bioaugmentation Pre-Demonstration Laboratory Control Spike Samples			
LCS-10187	03/29/02	105	Yes
LCS-10232	04/04/02	102	Yes
First Sampling Event During the Bioaugmentation Demonstration			
LCS-12029	12/18/02	99.3	Yes
LCS-12018	12/17/02	79.1	Yes
Second Sampling Event During the Bioaugmentation Demonstration			
LCS-12712	03/24/03	102	Yes
Bioaugmentation Post-Demonstration Laboratory Control Spike Samples			
LCS-13623	06/29/03	110	Yes
LCS-13628	06/30/03	117	Yes
LCS-13659	07/02/03	114	Yes

Table F-15. Method Blank Sample Analysis During the Bioaugmentation Demonstration Groundwater Sampling Events

Bioaugmentation Demonstration Groundwater QA/QC QA/QC Target Level TCE < 3.0 ug/L		Total Number of Samples Collected = 43 [Pre- (9); During (24); Post- (10)] Total Number of Method Blank Samples Analyzed = 8	
Sample ID	**Sample Date**	**TCE Recovery (ug/L)**	**Met QA/QC Criteria?**
Bioaugmentation Pre-Demonstration Method Blank Samples			
MB-10187	03/29/02	<1.0	Yes
MB-10232	04/04/02	<1.0	Yes
First Sampling Event During the Bioaugmentation Demonstration			
MB-12029	12/18/02	<1.0	Yes
MB-12018	12/17/02	<1.0	Yes
Second Sampling Event During the Bioaugmentation Demonstration			
MB-12712	03/24/03	<1.0	Yes
Bioaugmentation Post-Demonstration Method Blank Samples			
MB-13623	06/29/03	<1.0	Yes
MB-13628	06/30/03	<1.0	Yes
MB-13659	07/02/03	<1.0	Yes

Appendix G

Economic Analysis Information

Appendix G

Economic Analysis Information

This appendix details the cost assessment for the application of the pump-and-treat (P&T) system for containment of a DNAPL source at Launch Complex 34, for a source zone that is the same size as the biostimulation and bioaugmentation treatment plot. Because the groundwater flow in this area is generally to the northeast, the DNAPL source could be contained by installing one or more extraction wells on the northeast side of the resistive heating plot. The life cycle cost of a pump-and-treat system can be compared to the cost of DNAPL source removal by the biostimulation and bioaugmentation treatment, as described in Section 7 of the main report.

Experience at previous sites indicates that the most efficient long-term P&T system is one that is operated at the minimum rate necessary to contain a plume or source zone (Cherry et al., 1996). Table G-1 shows a preliminary size determination for the P&T system. The P&T system should be capable of capturing the groundwater flowing through a cross-section that is approximately 40 ft wide (width of a realistic contamination for the biostimulation and bioaugmentation plot) and 30 ft deep (thickness of the treatment target depth). Because capture with P&T systems is somewhat inefficient in that cleaner water from surrounding parts of the aquifer may also be drawn in, an additional safety factor of 100% was applied to ensure that any uncertainties in aquifer capture zone or DNAPL source characterization are accounted for. An extraction rate of 2 gallon per minute (gpm) is found to be sufficient to contain the source.

One advantage of low groundwater extraction rates is that the air effluent from stripping often does not have to be treated, as the rate of VOC discharge to the ambient air is often within regulatory limits. The longer period of operation required (at a low withdrawal rate) is more than offset by higher efficiency (lower influx of clean water from outside the plume), lower initial capital investment (smaller treatment system), and lower annual O&M requirements. Another advantage of a containment type P&T system is that, unlike source removal technologies, it does not require very extensive DNAPL zone characterization.

G.1 Capital Investment for the P&T System

The P&T system designed for this application consists of the components shown in Table G-2. Pneumatically driven pulse pumps, which are used in each well, are safer than electrical pumps in the presence of TCE vapors in the wells. This type of pump can sustain low flowrates during continuous operation. Stainless steel and Teflon™ construction ensure compatibility with the high concentrations (up to 1,100 mg/L TCE) of dissolved solvent and any free-phase DNAPL that may be expected. Extraction wells are assumed to be 30 ft deep, 2 inches in diameter, and have stainless steel screens with PVC risers.

The aboveground treatment system consists of a DNAPL separator and air stripper. Very little free-phase solvent is expected and the separator may be disconnected after the first year of operation, if desired. The air stripper used is a low-profile tray-type air stripper. As opposed to conventional packed towers, low-profile strippers have a smaller footprint, much smaller height, and can handle large air:water ratios (higher mass transfer rate of contaminants) without generating significant pressure losses. Because of their small size and easy installation, they are more often used in groundwater remediation. The capacity of the air stripper selected is much higher than 2 gpm, so that additional flow (or additional extraction wells) can be handled if required.

The high air:water ratio ensures that TCE (and other minor volatile components) are removed to the desired levels. The treated water effluent from the air stripper is discharged to the sewer. The air effluent is treated with a catalytic oxidation unit before discharge.

The piping from the wells to the air stripper is run through a 1-ft-deep covered trench. The air stripper and other associated equipment are housed on a 20-ft-x-20-ft concrete pad, covered by a basic shelter. The base will provide a power drop (through a pole transformer) and a licensed electrician will be used for the power hookups. Meters and control valves are strategically placed to control water and air flow through the system.

The existing monitoring system at the site will have to be supplemented with seven long-screen (10-foot screen) monitoring wells. The objective of these wells is to ensure that the desired containment is being achieved.

G.2 Annual Cost of the P&T System

The annual costs of P&T are shown in Table G-3 and include annual O&M. Annual O&M costs include the labor, materials, energy, and waste disposal cost of operating the system and routine maintenance (including scheduled replacement of seals, gaskets, and O-rings). Routine monitoring of the stripper influent and effluent is done through ports on the feed and effluent lines on a monthly basis. Groundwater monitoring is conducted on a quarterly basis through seven monitoring wells. All water samples are analyzed for PCE and other CVOC by-products.

G.3 Periodic Maintenance Cost

In addition to the routine maintenance described above, periodic maintenance will be required, as shown in Table G-3, to replace worn-out equipment. Based on manufacturers' recommendations for the respective equipment, replacement is done once in 5 or 10 years. In general, all equipment involving moving parts is assumed will be replaced once every 5 years, whereas other equipment is changed every 10 years.

G.4 Present Value (PV) Cost of P&T

Because a P&T system is operated for the long term, a 30-year period of operation is assumed for estimating cost. Because capital investment, annual costs, and periodic maintenance costs occur at different points in time, a life cycle analysis or present value analysis is conducted to estimate the long-term cost of P&T in today's dollars. This life cycle analysis approach is recommended for long-term remediation applications by the guidance provided in the Federal Technologies Roundtable's *Guide to Documenting and Managing Cost and Performance Information for Remediation Projects* (United States Environmental Protection Agency [U.S. EPA], 1998). The PV cost can then be compared with the cost of faster (DNAPL source reduction) remedies.

$$PV_{\text{P\&T costs}} = \sum \frac{\text{Annual Cost in Year t}}{(1 + r)^t} \qquad \text{Equation (G-1)}$$

$$PV_{\text{P\&T costs}} = \text{Capital Investment} + \frac{\text{Annual cost in Year 1}}{(1 + r)^1} + \ldots + \frac{\text{Annual cost in Year n}}{(1 + r)^n}$$

Equation (G-2)

Table G-3 shows the PV calculation for P&T based on Equation G-1. In Equation G-1, each year's cost is divided by a discount factor that reflects the rate of return that is foregone by incurring the cost. As seen in Equation G-2, at time t = 0, which is in the present, the cost incurred is the initial capital investment in equipment and labor to design, procure, and build the P&T system. Every year after that, a cost is incurred to operate and maintain the P&T system. A real rate of return (or discount rate), r, of 2.9% is used in the analysis as per recent U.S. EPA guidance on discount rates (U.S. EPA, 1999). The total PV cost of purchasing, installing, and operating a 2-gpm P&T source containment system for 30 years is estimated to be **$1,393,000** (rounded to the nearest thousand).

Long-term remediation costs are typically estimated for 30-year periods as mentioned above. Although the DNAPL source may persist for a much longer time, the contribution of costs incurred in later years to the PV cost of the P&T system is not very significant and the total 30-year cost is indicative of the total cost incurred for this application. This can be seen from the fact that in Years 28, 29, and 30, the differences in cumulative PV cost are not as significant as the difference in, say, Years 2, 3, and 4. The implication is that, due to the effect of discounting, costs that can be postponed to later years have a lower impact than costs that are incurred in the present.

As an illustration of a DNAPL source that may last much longer than the 30-year period of calculation, Figure G-1 shows a graphic representation of PV costs assuming that the same P&T system is operated for 100 years instead of 30 years. The PV cost curve flattens with each passing year. The total PV cost after 100 years (in Table G-4) is estimated at $2,179,000.

Table G-1. Pump-and-Treat (P&T) System Design Basis

Item	Value	Units	Item	Value	Units
Width of DNAPL zone, w	40	ft	Hyd. conductivity, K	40	ft/d
Depth of DNAPL zone, d	30	ft	Hyd. gradient, I	0.0007	ft/ft
Crossectional area of DNAPL zone, a	1,200	sq ft	Porosity, n	0.3	
Capture zone required	900	ft^3/d	Gw velocity, v	0.75	ft/d
Safety factor, 100%	2				
Required capture zone	1,800	ft^3/d	GPM =	2.0	gpm
Design pumping rate	2	gpm	Number of wells to achieve capture	1	
Pumping rate per well	2	gpm			
TCE conc. in water near DNAPL zone	100	mg/L	TCE allowed in discharge water	1	mg/L
Air stripper removal efficiency required	99.00%				
TCE in air effluent from stripper	2.4	lbs/day	TCE allowed in air effluent	6	lbs/day

Table G-2a. Capital Investment for a P&T System at Launch Complex 34, Cape Canaveral

Item	# units		Unit Price	Cost	Basis
Design/Procurement					
Engineer	120	hrs	$ 85	$10,200	
Drafter	80	hrs	$ 40	$3,200	
Hydrologist	120	hrs	$ 85	$10,200	
Contingency	1	ea	$ 10,000	$10,000	10% of total capital
TOTAL				$23,600	
Pumping system					
Extraction wells	1	ea	$ 5,000	$5,000	2-inch, 30 ft deep, 30-foot SS screen; PVC; includes installation
Pulse pumps	1	ea	$ 595	$595	2.1 gpm max., 1.66"OD for 2-inch wells; handles solvent contact; pneumatic; with chec valves
Controllers	1	ea	$ 1,115	$1,115	Solar powered or 110 V; with pilot valve
Air compressor	1	ea	$ 645	$645	100 psi (125 psi max), 4.3 cfm continuous duty, oil-less; 1 hp
Miscellaneous fittings	1	ea	$ 5,000	$5,000	Estimate
Tubing	150	ft	$ 3	$509	1/2-inch OD, chemical resistant; well to surface manifold
TOTAL				$12,864	
Treatment System					
Piping	150	ft	$ 3	$509	chemical resistant
Trench	1	day	$ 320	$320	ground surface
DNAPL separarator tank	1	ea	$ 120	$120	125 gal; high grade steel with epoxy lining; conical bottom with discharge
Air stripper feed pump	1	ea	$ 460	$460	0.5 hp; up to 15 gpm
Piping	50	ft	$ 3	$170	0.5 inch, chemical resistant; feed pump to stripper
Water flow meter	1	ea	$ 160	$160	Low flow; with read out
Low-profile air stripper with control panel	1	ea	$ 9,400	$9,400	1-25 gpm, 4 tray; SS shell and trays
Pressure gauge	1	ea	$ 50	$50	SS; 0-30 psi
Blower	1	ea	$ 1,650	$1,650	5 hp
Air flow meter	1	ea	$ 175	$175	Orifice type; 0-50 cfm
Stack	10	ft	$ 2	$20	2 inch, PVC, lead out of housing
Catalytic Oxidizer	1	ea	$ 65,000	$65,000	
Carbon	2	ea	$ 1,000	$2,000	
Stripper sump pump	1	ea	$ 130	$130	To sewer
Misc. fittings, switches	1	ea	$ 5,000	$5,000	Estimate (sample ports, valves, etc.)
TOTAL				$85,163	
Site Preparation					
Conctrete pad	400	ft^2	$ 3	$1,200	20 ft x 20 ft with berm; for air stripper and associated equipment
Berm	80	ft	$ 7	$539	
Power drop	1	ea	$ 5,838	$5,838	240 V, 50 Amps; pole transformer and licensed electrician
Monitoring wells	5	wells	$ 2,149	$10,745	Verify source containment; 2-inch PVC with SS screens
Sewer connection fee	1	ea	$ 2,150	$2,150	
Sewer pipe	300	ft	$ 10	$3,102	
Housing	1	ea	$ 2,280	$2,280	20 ft x 20 ft; shelter for air stripper and associated equipment
TOTAL				$25,854	
Installation/Start Up of Treatment System					
Engineer	60	hrs	$ 85	$5,100	Labor
Technician	200	hrs	$ 40	$8,000	Labor
TOTAL				$13,100	
TOTAL CAPITAL INVESTMENT				**$160,581**	

Table G-2b. O&M Costs for a P&T System at Launch Complex 34, Cape Canaveral

O&M Cost for P&T Sytem					
Annual Operation & Maintenance					
Engineer	80	hrs	$ 85	$6,800	Oversight
Technician	500	hrs	$ 40	$20,000	Routine operation; annual cleaning of air stripper trays, routine replacement of parts; any waste disposal
Replacement materials	1	ea	$ 2,000	$2,000	Seals, o-rings, tubing, etc.
Electricity	52,560	kW-hrs	$ 0	$5,256	8 hp (~6 kW) over 1 year of operation
Fuel (catalytic oxidizer)	2,200	10^6 Btu	$ 6	$13,200	
Sewer disposal fee	525,600	gal/yr	$ 0	$799	
Carbon disposal	2		$ 1,000	$2,000	
Waste disposal	20	drum	$ 80	$1,600	20 gal drum; DNAPL, if any; haul to incinerator
TOTAL				$51,655	
Annual Monitoring					
Air stripper influent	12	samples	$ 120	$1,440	Verify air stripper loading; monthly
Air stripper effluent	14	samples	$ 120	$1,680	Discharge quality confirmation; monthly; CVOC analysis; MS, MSD
Monitoring wells	20	samples	$ 120	$2,400	5 wells; quarterly; MS, MSD
Sampling materials	1	ea	$ 500	$500	Miscellaneous
Technician	64	hrs	$ 40	$2,560	Quarterly monitoring labor (from wells) only; weekly monitoring (from sample ports) included in O&M cost
Engineer	40	hrs	$ 85	$3,400	Oversight; quarterly report
TOTAL				$5,520	
TOTAL ANNUAL COST				**$57,175**	
Periodic Maintenance, Every 5 years					
Pulse pumps	4	ea	$ 595	$2,380	As above
Air compressor	1	ea	$ 645	$645	As above
Air stripper feed pump	1	ea	$ 460	$460	As above
Blower	1	ea	$ 1,650	$1,650	As above
Catalyst replacement	1	ea	$ 5,000	$5,000	
Stripper sump pump	1	ea	$ 130	$130	As above
Miscellaneous materials	1	ea	$ 1,000	$1,000	Estimate
Technician	40	hrs	$ 40	$1,600	Labor
TOTAL				**$12,865**	
				$70,040	
Periodic Maintenance, Every 10 years					
Air stripper	1	ea	$ 9,400	$9,400	As above
Catalytic oxidizer	1	ea	$ 16,000	$16,000	Major overhaul
Water flow meters	1	ea	$ 160	$160	As above
Air flow meter	1	ea	$ 175	$175	As above
Technician	40	hrs	$ 40	$1,600	Labor
Miscellaneous materials	1	ea	$ 1,000	$1,000	Estimate
TOTAL				**$28,335**	
TOTAL PERIODIC MAINTENANCE COSTS				**$98,375**	

Table G-3. Present Value of P&T System Costs for 30-Year Operation

Year	P&T		
	Annual Cost *	PV of Annual Cost	Cumulative PV of Annual Cost
0	**$160,581**	$160,581	$160,581
1	$57,175	$55,564	$216,144
2	$57,175	$53,998	$270,142
3	$57,175	$52,476	$322,618
4	$57,175	$50,997	$373,615
5	**$70,040**	$60,711	$434,326
6	$57,175	$48,163	$482,489
7	$57,175	$46,806	$529,294
8	$57,175	$45,486	$574,781
9	$57,175	$44,205	$618,985
10	**$98,375**	$73,915	$692,900
11	$57,175	$41,748	$734,648
12	$57,175	$40,571	$775,220
13	$57,175	$39,428	$814,648
14	$57,175	$38,317	$852,965
15	**$70,040**	$45,616	$898,580
16	$57,175	$36,188	$934,768
17	$57,175	$35,168	$969,936
18	$57,175	$34,177	$1,004,112
19	$57,175	$33,213	$1,037,326
20	**$98,375**	$55,536	$1,092,862
21	$57,175	$31,368	$1,124,230
22	$57,175	$30,484	$1,154,713
23	$57,175	$29,625	$1,184,338
24	$57,175	$28,790	$1,213,128
25	**$70,040**	$34,274	$1,247,401
26	$57,175	$27,190	$1,274,591
27	$57,175	$26,424	$1,301,015
28	$57,175	$25,679	$1,326,693
29	$57,175	$24,955	$1,351,649
30	**$98,375**	$41,728	$1,393,376

* Annual cost in Year zero is equal to the capital investment.
Annual cost in other years is annual O&M cost plus annual monitoring cost
Annual costs in Years 10, 20, and 30 include annual
O&M, annual monitoring, and periodic maintenance

Table G-4. Present Value of P T System for 100-Year Operation

Year	P&T Annual Cost *	P&T PV of Annual Cost	P&T Cumulative PV of Annual Cost
0	**$160,581**	$160,581	$160,581
1	$57,175	$55,564	$216,144
2	$57,175	$53,998	$270,142
3	$57,175	$52,476	$322,618
4	$57,175	$50,997	$373,615
5	**$70,040**	$60,711	$434,326
6	$57,175	$48,163	$482,489
7	$57,175	$46,806	$529,294
8	$57,175	$45,486	$574,781
9	$57,175	$44,205	$618,985
10	**$98,375**	$73,915	$692,900
11	$57,175	$41,748	$734,648
12	$57,175	$40,571	$775,220
13	$57,175	$39,428	$814,648
14	$57,175	$38,317	$852,965
15	**$70,040**	$45,616	$898,580
16	$57,175	$36,188	$934,768
17	$57,175	$35,168	$969,936
18	$57,175	$34,177	$1,004,112
19	$57,175	$33,213	$1,037,326
20	**$98,375**	$55,536	$1,092,862
21	$57,175	$31,368	$1,124,230
22	$57,175	$30,484	$1,154,713
23	$57,175	$29,625	$1,184,338
24	$57,175	$28,790	$1,213,128
25	**$70,040**	$34,274	$1,247,401
26	$57,175	$27,190	$1,274,591
27	$57,175	$26,424	$1,301,015
28	$57,175	$25,679	$1,326,693
29	$57,175	$24,955	$1,351,649
30	**$98,375**	$41,728	$1,393,376
31	$57,175	$23,568	$1,416,944
32	$57,175	$22,904	$1,439,849
33	$57,175	$22,259	$1,462,107
34	$57,175	$21,631	$1,483,739
35	**$70,040**	$25,752	$1,509,490
36	$57,175	$20,429	$1,529,920
37	$57,175	$19,853	$1,549,773
38	$57,175	$19,294	$1,569,067
39	$57,175	$18,750	$1,587,817
40	**$98,375**	$31,352	$1,619,169
41	$57,175	$17,708	$1,636,878
42	$57,175	$17,209	$1,654,087
43	$57,175	$16,724	$1,670,811
44	$57,175	$16,253	$1,687,064
45	**$70,040**	$19,349	$1,706,413
46	$57,175	$15,350	$1,721,762
47	$57,175	$14,917	$1,736,679
48	$57,175	$14,497	$1,751,176
49	$57,175	$14,088	$1,765,264
50	**$98,375**	$23,557	$1,788,821

Year	P&T Annual Cost *	P&T PV of Annual Cost	P&T Cumulative PV of Annual Cost
51	$57,175	$13,305	$1,802,126
52	$57,175	$12,930	$1,815,056
53	$57,175	$12,566	$1,827,622
54	$57,175	$12,212	$1,839,834
55	**$70,040**	$14,538	$1,854,372
56	$57,175	$11,533	$1,865,905
57	$57,175	$11,208	$1,877,113
58	$57,175	$10,892	$1,888,005
59	$57,175	$10,585	$1,898,590
60	**$98,375**	$17,700	$1,916,290
61	$57,175	$9,997	$1,926,286
62	$57,175	$9,715	$1,936,002
63	$57,175	$9,441	$1,945,443
64	$57,175	$9,175	$1,954,618
65	**$70,040**	$10,923	$1,965,542
66	$57,175	$8,665	$1,974,207
67	$57,175	$8,421	$1,982,628
68	$57,175	$8,184	$1,990,812
69	$57,175	$7,953	$1,998,765
70	**$98,375**	$13,299	$2,012,064
71	$57,175	$7,511	$2,019,575
72	$57,175	$7,300	$2,026,875
73	$57,175	$7,094	$2,033,969
74	$57,175	$6,894	$2,040,863
75	**$70,040**	$8,207	$2,049,070
76	$57,175	$6,511	$2,055,581
77	$57,175	$6,327	$2,061,908
78	$57,175	$6,149	$2,068,057
79	$57,175	$5,976	$2,074,033
80	**$98,375**	$9,992	$2,084,025
81	$57,175	$5,644	$2,089,669
82	$57,175	$5,485	$2,095,153
83	$57,175	$5,330	$2,100,483
84	$57,175	$5,180	$2,105,663
85	**$70,040**	$6,167	$2,111,829
86	$57,175	$4,892	$2,116,721
87	$57,175	$4,754	$2,121,476
88	$57,175	$4,620	$2,126,096
89	$57,175	$4,490	$2,130,586
90	**$98,375**	$7,508	$2,138,093
91	$57,175	$4,240	$2,142,334
92	$57,175	$4,121	$2,146,454
93	$57,175	$4,005	$2,150,459
94	$57,175	$3,892	$2,154,351
95	**$70,040**	$4,633	$2,158,984
96	$57,175	$3,676	$2,162,660
97	$57,175	$3,572	$2,166,232
98	$57,175	$3,471	$2,169,703
99	$57,175	$3,374	$2,173,077
100	**$98,375**	$5,641	$2,178,718

Figure G-1. P&T System Total Costs over 100 years